agence d'évaluation de la recherche et de l'enseignement supérieur

Dossier d'évaluation
d'une unité de recherche

Vague E : campagne d'évaluation 2013-2014

Évaluation du

Laboratoire Spécification & Vérification (LSV – UMR 8643)

de l'École Normale Supérieure de Cachan

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► Information sur l'unité de recherche

Nom de l'unité : Laboratoire Spécification & Vérification
Acronyme : L.S.V.
Nom du directeur pour le contrat en cours : Laurent FRIBOURG
Nom du directeur pour le contrat à venir : Laurent FRIBOURG

► Type de demande

Renouvellement à l'identique ☑ Restructuration ☐ Création ex nihilo ☐

► Choix de l'évaluation interdisciplinaire de l'unité de recherche

Oui ☐ Non ☑

Dossier d'évaluation

1 Présentation de l'unité

Fondé en 1997, le Laboratoire Spécification et Vérification (LSV) est le laboratoire d'informatique de l'ENS de Cachan, et est aussi affilié au Centre National de la Recherche Scientifique (CNRS) en tant qu'UMR 8643. La recherche au LSV est centrée sur la vérification de logiciels et systèmes critiques, et sur la vérification de la sécurité des systèmes informatiques. Il bénéficie du soutien de INRIA depuis 2002. Il compte aujourd'hui 24 membres permanents, 16 doctorants, 8 membres associés et 6 membres de support administratif et technique.

1.1 Politique scientifique

Le LSV consacre l'essentiel de ses recherches aux problèmes de la spécification et de la vérification des systèmes critiques. Il s'agit de développer des langages et des méthodes formelles permettant d'énoncer et de démontrer la correction de ces systèmes. Ces méthodes conduisent parfois au développement d'outils logiciels utilisés pour automatiser les preuves de correction ou, a contrario, la détection d'erreurs.

1.2 Profil d'activités

Le laboratoire est organisé en cinq axes, correspondant à cinq grands domaines d'application de nos techniques.

1. Axe DAHU : spécification et vérification des systèmes qui, tels les services web, reposent sur la manipulation de grandes bases de données distribuées. Membres permanents : Serge Abiteboul, Cristina Sirangelo, Luc Segoufin (responsable).
2. Axe INFINI : vérification automatique des systèmes infinis (programmes manipulant des données non bornées, processus communicant de façon mutuellement récursive, systèmes paramétrés, etc.). Membres permanents : Stéphane Demri, Laurent Doyen, Alain Finkel (responsable), Sylvain Schmitz, Philippe Schnoebelen.
3. Axe MEXICO : vérification des systèmes distribués et concurrents. Membres permanents : Benedikt Bollig, Thomas Chatain, Paul Gastin, Stefan Haar (responsable), Serge Haddad, Stefan Schwoon.
4. Axe SECSI : sécurité des systèmes d'information, allant de la vérification de protocoles de sécurité à la détection d'intrusions. Membres permanents : David Baelde, Hubert Comon-Lundh, Stéphanie Delaune, Jean Goubault-Larrecq (responsable).
5. Axe TEMPO : vérification des systèmes temps-réel, où la prise en compte des aspects temporisés est essentielle pour énoncer la correction. Membres permanents : Dietmar Berwanger, Patricia Bouyer-Decitre, Laurent Fribourg, Nicolas Markey (responsable), Claudine Picaronny.

Les axes DAHU, MEXICO et SECSI sont des projets de INRIA Saclay – Île-de-France.

Depuis novembre 2006, le LSV est membre de l'institut Farman, qui regroupe cinq laboratoires de l'ENS Cachan autour de la modélisation, la simulation, et la vérification des systèmes complexes.

1.3 Organisation et vie de l'unité

- **Evolution des effectifs.** Depuis 2008, les effectifs en chercheurs et enseignants-chercheurs ont légèrement augmenté passant de 21 en 2008 à 24 en 2013. Précisément, ceux qui ont rejoint le LSV sont : S. Abiteboul (DR INRIA), D. Berwanger (CR CNRS), S. Schmitz (MC ENS Cachan) et C. Sirangelo (MC ENS Cachan) en 2008 ; L. Doyen (CR CNRS) et S. Schwoon (MC ENS Cachan – Chaire INRIA) en 2009 ; D. Baelde (MC ENS Cachan) en 2012. Ceux qui ont quitté le LSV sont : F. Jacquemard (CR INRIA) et S. Kremer (CR INRIA) en 2011, G. Steel (CR INRIA) en 2012 ; É. Lozes (MC ENS Cachan) en détachement en Allemagne depuis 2010 (souhaite revenir en France sur un poste de professeur hors ENS Cachan).
- **Thèses soutenues.** Durant la période janvier 2008 – juin 2013, 28 thèses de doctorat (3 en 2008, 5 en 2009, 6 en 2010, 7 en 2011, 5 en 2012, 2 entre janvier et juin 2013) et 8 HDR (1 en 2009, 5 en 2011, 2 en 2012) ont été soutenues au LSV. Sur les 28 personnes ayant soutenu une thèse, 6 ont aujourd'hui un poste de MC (4 en France, 1 en Roumanie, 1 en Inde), 1 a un poste de CR CNRS, 8 sont en post-doc à l'étranger, les autres sont professeurs en classes spéciales, ingénieurs ou experts techniques dans des ministères.

  Notons que par année, nous avons en moyenne 18 doctorants inscrits pour 15 HDR, ce qui correspond à un peu plus d'un doctorant par HDR. Ce chiffre peut paraître faible. Nous aurions sans doute la capacité d'encadrer davantage de doctorants. Il est en partie compensé par un taux remarquable d'accession de nos étudiants à la vie universitaire et académique.
- **Liens avec INRIA.** Alors que seul l'axe SECSI correspondait à une Équipe-Projet Commune (EPC) avec l'INRIA en décembre 2007, deux autres axes EPC ont été créés en 2008 et 2009, à savoir DAHU et MEXICO. La création de l'axe DAHU a été renforcé par l'arrivée de Serge Abiteboul en décembre 2008 et le flux important des post-docs et chercheurs invités associés à son projet ERC Webdam ; l'axe MEXICO a correspondu à une restructuration de l'axe TEMPO qui s'est recentré sur sa composante « temporisée », après le passage de sa composante « systèmes distribués » dans MEXICO. La constitution de trois axes du LSV sur cinq en tant qu'EPC a naturellement renforcé la collaboration avec INRIA. Les trois EPC ont ainsi un processus d'évaluation quadri-annuelle par INRIA (dernière en date : 2010 pour MEXICO, 2011 pour SECSI, 2011 pour DAHU). La négociation de la contractualisation d'INRIA comme troisième co-tutelle du LSV (en sus de l'ENS Cachan et du CNRS) a débuté en 2012, mais n'a pas encore abouti pour des raisons essentiellement de calendrier.

- **Vie intérieure.** Le LSV a maintenu sa façon d'organiser sa vie intérieure qui a assuré depuis sa création une forte cohésion et l'implication de tous ses membres dans les tâches d'intérêt collectif :
  - comité de direction hebdomadaire (mardi, 10h-11h) ouvert à tous (ITA, représentant des doctorants compris), où est évoquée l'actualité non seulement du laboratoire mais du département,
  - séminaire hebdomadaire (mardi, 11h-12h), donné par un intervenant extérieur, suivi par tous les membres du LSV ainsi que, régulièrement, plusieurs membres extérieurs,
  - séminaire annuel de trois jours (fin mai ou début juin) à Barbizon ou un endroit proche de Paris, où tout le laboratoire échange des informations scientifiques, techniques et administratives.

1.4 Faits marquants

On présente cinq résultats qui ont eu un impact scientifique ces cinq dernières années, ou nous paraissent être porteurs d'impact pour les cinq prochaines années.

1. **Analyse d'APIs de sécurité (CI-44).** L'API PKCS#11 est aujourd'hui l'interface standard de sécurité la plus utilisée dans l'industrie. Par des méthodes de reverse-engineering automatisé et de démonstration automatique, l'outil Tookan, développé au LSV, découvre des bugs de sécurité dans des dispositifs PKCS#11 commerciaux (cartes à puce, hardware security modules, tokens de sécurité), et a ainsi mis à jour plus d'une douzaine de nouvelles attaques. Ce travail a fait l'objet d'articles dans le New York Times, le Boston Globe, le Suddeutscher Zeitung.

2. **XML avec information incomplète (RI-66).** La structure des documents XML est beaucoup plus compliquée que celle des bases de données relationnelles. En particulier, la gestion d'information incomplète est beaucoup plus difficile. Ce travail donne une étude systématique de l'information incomplète dans les documents XML en visant à la rendre indépendante de l'application visée. Nous donnons des classes de description de l'information incomplète qui sont robustes et débouchent sur des solutions algorithmiques efficaces.

3. **Synthèse distribuée pour systèmes à communications asynchrones (RI-118).** On cherche ici à dériver automatiquement un programme pour un système dont toutes les exécutions satisfont une spécification donnée et ce, quelle que soit la façon dont l'environnement se comporte. Pour le problème de synthèse de systèmes *distribués*, on se donne en outre une description des communications possibles entre les différents processus du système, ainsi que des communications entre l'environnement et les processus. Le but est de synthétiser automatiquement un programme pour chaque processus du système. Comme l'ont montré Pnueli et Rosner en 1990, ce dernier problème est indécidable en général. Le travail présent porte sur des systèmes ayant un comportement asynchrone. Un nouveau modèle de communication par *signaux* est introduit : un signal correspond ici à une action commune à deux processus, mais contrôlée par un seul. On montre que, dans ce cadre, le problème de synthèse est décidable pour les systèmes dont le graphe de communication est fortement connexe.

4. **Robustesse des systèmes temporisés (CI-50).** Nous proposons une méthode de synthèse des stratégies *robustes* garantissant l'atteignabilité d'un état-cible pour les automates temporisés. Par *robuste*, nous voulons dire que l'atteignabilité est obtenue, même en présence de petites perturbations induites par l'environnement sur les valeurs nominales des délais des automates. La sémantique de l'automate perturbé par l'environnement est modélisée sous forme de jeu entre contrôleur et environnement. On montre que l'atteignabilité se ramène à l'existence d'une borne supérieure sur la valeur des perturbations pour laquelle la construction d'une stratégie gagnante est un problème EXPTIME-complet.

5. **Well-quasi-orderings et complexité (CI-126).** Ce travail montre que les well-quasi-orderings peuvent être utilisés non seulement pour montrer la terminaison d'algorithmes, mais aussi, pour établir des bornes supérieures de complexité. En particulier, des bornes supérieures de complexité optimales sont extraites des preuves de terminaison à base du lemme de Dickson, pour des programmes à compteurs et structures de données associées.

1.5 Rayonnement et attractivité académiques

En ce qui concerne le rayonnement et la participation à la vie scientifique, parmi les nombreux prix, distinctions, participations à des instances de pilotage et d'évaluation impliquant des membres du LSV sur la période 2008-2013, signalons :

- Serge Abiteboul : ERC Advanced Grant (2009-2013), Chaire au collège de France (2012), membre du Conseil National du Numérique (2012), de l'Académie des sciences (2011), de l'Academia Europea (2012), ACM Fellow (2012),
- Michel Bidoit : nommé Directeur du département INS2I du CNRS (2013),
- Patricia Bouyer : ERC Starting Grant (2012-2015), Presburger EATCS Award (2011), membre élue du CoNRS (2012-2015),
- Hubert Comon-Lundh : médaille d'argent CNRS (2008),
- Stéphane Demri : lauréat d'une bourse Marie Curie extra-européenne (2012-2014),
- Laurent Fribourg : membre élu du bureau du Sénat Académique du campus Paris-Saclay (2013),
- Jean Goubault-Larrecq : médaille d'argent CNRS (2011),
- Philippe Schnoebelen : membre élu du CoNRS (2008-2012).

Par ailleurs, sur la période 2008-2013, les membres du LSV ont été *Program Chairs* ou *Conference Chairs* de 15 conférences internationales, et membres de 22 comités d'évaluation AERES. Voir annexe « Rayonnements et distinctions » pour un panorama plus détaillé.

En ce qui concerne l'attractivité, mentionnons que le LSV a obtenu pour des chercheurs étrangers :

- une chaire INRIA/MC ENS Cachan attribuée à Stefan Schwoon (2009-2014),
- une chaire d'excellence RBUCE-UP (FP7 - Marie Curie) attribuée à Giuseppe Lipari (2012-2014),
- une chaire d'excellence DIGITEO attribuée à Pierre McKenzie (2013-2015).

1.6 Interactions avec l'environnement social, économique et culturel

- Participation à la diffusion de la culture scientifique et l'engagement vis-à-vis de problèmes socio-économiques :
  1. Serge Abiteboul : co-rédacteur du rapport de l'Académie des Sciences sur l'Enseignement de l'Informatique en France (mai 2013) ; rédacteur principal du rapport sur la neutralité d'Internet du Comité National du Numérique (2013) ; a donné au Collège de France un cours de très haut niveau montrant l'impact de la logique du 1er ordre sur le monde moderne (2012) ; a donné des dizaines d'interviews radiophoniques et journalistiques sur la période 2008-2013.
  2. Paul Gastin a donné plusieurs séminaires à destination des professeurs de lycée (terminales, classes préparatoires) à l'ENS Cachan (juin 2010) et au CIRM de Marseille (mai 2013) pour sensibiliser et former des professeurs suite à l'introduction de l'informatique en terminale scientifique et à la modification du programme de l'option informatique des classes préparatoires.
  3. Jean Goubault-Larrecq a participé à plusieurs journées de communication et diffusion du logiciel de détection d'intrusion ORCHIDS à destination des industriels (speed-dating *iMatch* organisé par INRIA Saclay en novembre 2010, journée INRIA Industrie en avril 2012, séminaire *DGA Innosciences* en juin 2013, . . .).
- Liste des brevets et contrats avec industriels :
  1. Certificat APP Tookan en 2011, et contrats INRIA avec Boeing en 2010, Barclays en 2010, HSBC en 2011 (CI-44).
  2. Contrat d'étude du LSV pour le cabinet AdviTech Partners en 2009 : étude de faisabilité de la startup SpidWare dans le domaine de la sécurité informatique.
  3. Projet blanc CPP (confiance, preuves et probabilités) en 2009-2013 avec LSV (coordinateur), CEA Saclay, INRIA, Supélec, Dassault Systèmes, Hispano-Suiza, Safran (ex. SagemCom).
  4. Certificat APP Orchids délivré en 2012, suivi d'une convention INRIA-DGA sur Orchids, 2013-2016.
  5. Contrat ANR VALMEM avec LSV (coordinateur), LIP6 et STMicroelectronics de 2007 à 2010 ; validation de la mémoire SPSMALL (RI-124).
  6. Contrat FARMAN entre LSV et EADS Astrium Space Technology, 2011-2012 (CI-38).

7. Accord CIFRE ENS Cachan-EADS : co-encadrement thèse Jean-Loup Carré (2007-2010) et participation au logiciel Penjili (propriétaire EADS) d'analyse statique de code C.
8. Contrats CIFRE avec EDF (thèse d'Arnaud Sangnier en 2008) et France Telecom/Orange (thèse de Camille Vacher en 2010).

Signalons enfin que le LSV, qui a recruté un ingénieur à plein temps à cet effet (2013-2014), joue un rôle moteur dans le développement et le déploiement de la plateforme CosyVerif, conçue en partenariat avec deux laboratoires parisiens (LIP6, LACL), et qui abrite plusieurs outils de modélisation et vérification implémentés au LSV (IMITATOR, CUNF, COSMOS).

2 Réalisations

2.1 Production scientifique

	2008	2009	2010	2011	2012	2013 jan.-juin	Total
ouvrages, chapitres, édition d'actes	7	20	5	12	4	4	52
revues internationales	22	23	40	16	34	12	147
invitations dans des conférences internationales	4	5	5	3	5	1	23
articles dans des conférences internationales	52	61	61	65	53	24	316
thèses de doctorat ou d'habilitation	4	6	6	12	7	2	37

Ce bilan appelle plusieurs remarques :

- Le bilan surpasse nettement et à tous les niveaux, celui de la période 2004-2008, alors que celui-ci était déjà remarquable.
- Cette information quantitative ne reflète pas l'excellence et la sélectivité des revues et conférences où paraissent ces publications (Information and Computation, Theoretical Computer Science, Logical Methods in Computer Science, J. Logic and Computation, SIAM J. of Computing, ACM Trans. on Computational Logic, J. Computer and System Sciences, Distributed Computing, ACM Trans. on Database and Systems, J. of Computer Security, Communications of the ACM, J. of the ACM, pour ne citer que quelques revues prestigieuses où sont parues nos publications en 2008-2013).
- Il n'y aurait pas beaucoup de sens à faire un bilan axe par axe, car de nombreuses publications sont co-signées par plusieurs membres d'axes différents.

Nous détaillons maintenant, axe par axe, le rapport scientifique de janvier 2008 à juin 2013[1].

2.2 Bilan scientifique

► Scientific report of axis dahu

The main goal of Dahu is to make database driven systems more reliable and more efficient. To achieve this we study problems such as specification and modelling of such systems, query evaluation and query optimization, verification. . .

During the evaluation period we have worked mainly on four objectives. The first one is tree automata theory, as those are implicit in many XML query languages and Schema languages. The second one is about distributed data management. The third one concerns the specification and verification of database driven systems. The last objective is about efficient evaluation of queries.

Objective 1 Tree automata theory

The links between models for XML and regular tree languages has been advocated in many places: Tree automata seem to be playing for semi-structured data and XML the role of the relational algebra for relational databases. As XML is central in our research, we have studied several models of tree automata with features that could be used for manipulating data. Not surprisingly, most of our results concern data words and data trees. Those are words and trees where each position contains a data value together with the classical label. Data trees can easily be seen as a model for XML data.

[1] Ces rapports sont en anglais car ils réutilisent des parties des rapports scientifiques écrits par les EPC pour INRIA.

We obtained results on register automata: These extend the classical model of finite automata with auxiliary registers storing data values for later comparison. We have shown that they are closely related with timed automata (CI-172) and obtained various decidability and expressiveness results on data words and data trees, linking them with various logical formalisms such as XPath. See for instance (RI-121, CI-225, CI-137, CI-198, CI-250).

We also studied automata with counters as several variants of this automata model were used successfully for showing decidability of the above-mentioned register automata. Results here concern decidability and complexity issues. See (CI-206, RI-90, CI-197).

We also studied the expressive power of subclasses of regular tree languages using algebraic methods. As an application we derived from one such result a precise information about the expressive power of the query language XPath. Some of the associated references are (CI-302, RI-95, CI-241, CI-187, RI-77, CI-173).

We have also considered models described by tree automata enriched with a test of isomorphism between subtrees. They can be used for testing monadic key constraints over XML documents. For these models, the main challenge is to establish the decidability of the non-emptiness of the language specified by a given automaton, this was achieved by different techniques in (RI-142, RI-138, CI-255, RI-61, CI-178).

Finally we have obtained results concerning the closure of tree automata languages under various kinds of rewriting systems. The goal here is to be able to characterize this closure (exactly or with approximations) using a decidable formalism. This approach is useful for the analysis of transformations formalisms for semi-structured data. It has been applied in particular to typechecking XQuery updates and verifying access control policies. Some associated references are (CI-291, CI-251, CI-186).

Objective 2 Distributed data management

The goal is to develop a formal model for Web data management that would open new horizons for the development of the Web in a well-principled way, enhancing its functionality, performance, and reliability. Specifically, the goal is to develop a universally accepted formal framework for describing complex and flexible interacting Web applications featuring notably data exchange, sharing, integration, querying and updating.

Major results were obtained on the following topics:

Distributed knowledge base. As a foundation for managing distribution (CI-62), we have proposed a model of a distributed knowledge base, that handles data and meta-data, as well as access control and localization, in a unique integrated setting. To support automatic reasoning on this knowledge base, we also introduced a novel rule-based language supporting the exchange of rules, namely Webdamlog. This work has been presented (CI-120) and demonstrated (CI-132) at major database conferences.

Probabilistic XML. Data from the Web are imprecise and uncertain. To manage this imprecision in a well-principled way, we have made significant advances in the field of probabilistic databases, and specifically, probabilistic XML. We have introduced new tractable probabilistic models for representing uncertain hierarchical information, and carried out in-depth studies of query evaluation, aggregation, and updates in various probabilistic XML models. See for instance (CI-195, RI-109).

Data exchange and Web incomplete information. We have addressed the problem of restructuring data exchanged between communicating applications on the Web. We have proposed and analyzed a new language to specify data restructuring rules (schema mappings). This language generalizes existing mapping dependencies, by allowing a more flexible specification mechanism (RI-57). The data restructuring process also naturally generates partial information. We have proposed a general model of XML incomplete information and have studied the main computational problems related to it, ranging from consistency of partial specification to query evaluation (RI-66, RI-101). We have also investigated the possibility of efficient query answering solutions in the presence of incomplete information. In particular we have studied an efficient evaluation strategy referred to as "naive", because it ignores data incompleteness. We have considered this procedure for queries over general data domains, with the objective of identifying suitable query fragments where naive evaluation works (CI-14).

Jorge. We also invested a lot of effort in a textbook (undergraduate and graduate level) on Web data management (nicknamed Jorge) published at Cambridge University Press (LI-4). See http://webdam.inria.fr/Jorge.

Objective 3 Specification and verification of database driven systems

This objective aims at making systems manipulating data safer and more reliable. This means providing suitable models together with a toolbox for helping in the design and implementation of such systems. These last years we have mainly worked on the modelling and the static analysis at various levels: query language and XML schema, access control policies and global specification of data-centric evolving systems.

Modelling and verification of data-centric systems. We have intensively studied the Active XML model, a high-level specification language tailored to data-intensive, distributed, dynamic Web services. Our first line of results concerns the verification of temporal properties of runs of Active XML systems, specified in a tree-pattern based temporal logic, Tree-LTL. Our second line of result is a comparison of the specification power of various workflow control mechanisms within the Active XML framework and beyond. For more details about this work see (CI-134, RI-104, CI-292)

We have also introduced a model of automata designed for modeling infinite runs of systems equipped with static relational databases. The automata model is equipped with finitely many registers for storing data values for later comparison. The transitions of the automata depends on a conjunctive query involving the database and the current values of the registers. Our main contribution is the proof that automated verification of temporal properties of systems modeled by such automata model can be carried out in PSpace. For more details, see (CI-139, CI-5).

Static analysis of query languages. XPath is arguably the most widely used XML query language as it is implemented in XSLT and XQuery and it is used as a constituent part of several specification and update languages. Hence in order to perform static analysis on a system manipulating XML data it is important to master the static analysis for XPath. In general, in the presence of data values, the satisfiability of XPath is undecidable. However we have shown that many important fragments can be decided. For more details, see for instance (CI-137, CI-198, CI-250, CI-225).

Static analysis of updates and access control policies. XQuery language has been extended to XQuery Update Facility (a W3C Recommendation of 2011) in order to provide convenient means of modifying XML documents. We proposed a model for these update primitives as parametrized rewriting rules and gave type inference algorithms for these rules, directly applicable to XML static typechecking and to the verification of XML access control policies. For more details, see (CI-186, CI-149, CI-232).

Objective 4 Enumeration of answers to a query

In many applications the output of a query may have a huge size and enumerating all the answers may already consume too many of the allowed resources. In this case it may be appropriate to first output a small subset of the answers and then, on demand, output a subsequent small numbers of answers and so on until all possible answers have been exhausted. To make this even more attractive it is preferable to be able to minimize the time necessary to output the first answers and, from a given set of answers, also minimize the time necessary to output the next set of answers—this second time interval is known as the *delay*. For this it might be interesting to compute adequate index structures. Recently, we have exhibited many scenarios (restrictions on the database) for which enumeration of first-order queries can be achieved in constant delay after a linear preprocessing. The relevant bibliography is (RI-56, CI-16).

► Scientific report of axis infini

Twenty-five years after its initial theoretical developments, the framework of *Well-structured transition systems* (WSTS), developed in an ample part by members of the INFINI axis, has become an invaluable tool in the verification of infinite-state systems. Such systems are endowed with a well quasi ordering (wqo) $\leq$ on their state space, which allows to obtain various decidability results.

The rate with which new WSTS models are defined and used is still not diminishing. The use and the study of wqo has been renewed in the last ten years.

Objective 1 Complete WSTS and WSTS Completions

One of the most useful decidable problems on WSTS for verification is *coverability*, because it allows to check safety properties: given states s and t, decide whether $s \geq s_1 \rightarrow^* t_1 \geq t$ for some s_1, t_1. This is decidable thanks to a now classical backward algorithm, that attempts to reach s backwards from the set of states that cover t. Nevertheless, forward procedures are felt to be more efficient than backward procedures in general: e.g., for lossy channel systems, although the backward procedure always terminates, only a (necessarily non-terminating) forward procedure is implemented in the TREX tool.We have derived similar generic algorithms that proceed *forward*: those algorithms compute instead the *cover* of s, i.e., the downward-closure of the reachability set from s (CI-262, CI-239, CI-123, IN-5, RI-29). This work draws from topological generalizations of wqos, and comprises two main contributions:

- We define a *complete WSTS* as a WSTS S whose well-ordering is also a continuous directed complete partial ordering. This allows us to design a conceptual procedure $\mathbf{Clover}_S$ that looks for a finite representation of the downward closure of the reachability set, i.e., of the cover. This clearly separates the fundamental ideas from the data structures used in implementing Karp-Miller-like algorithms. Our procedure also terminates in more cases than the (generalized) Karp-Miller procedure. We characterize the complete WSTS for which $\mathbf{Clover}_S$ terminates. These are the ones that have a (continuous) flattening with the same clover.
- Building on our theory of completions (CI-262), we characterize those WSTS whose completion is a complete WSTS in the sense above. They are exactly the ω^2-*WSTS*, i.e., those whose state space is an ω^2-wqo. All naturally occurring WSTS are in fact ω^2-WSTS. Despite the fact that $\mathbf{Clover}_S$ cannot terminate on all inputs, that S is an ω^2-WSTS will ensure *progress*, i.e., that every opportunity of accelerating a loop will eventually be taken by $\mathbf{Clover}_S$.

Objective 2 Algorithmic Theory of WQOs

Except in a few pioneering works, the computational costs of WSTS-based methods has not really been analyzed or even addressed until recently. The explanation behind this omission is that the computer science community was lacking concepts and results on the complexity of the most commonly used wqos, beginning with tuples of natural numbers and words ordered by embedding. This issue goes beyond WSTS and verification.

In the last five years, we developed a theoretical framework that allows to measure the complexity of algorithms (and problems) involving these wqos:

- Complexity upper bounds are obtained by careful computations in the ordinal-recursive hierarchies first considered in Recursion theory and in Proof Theory. Our work here has a strong combinatorial flavor (CI-126, CI-119). We managed to provide upper bounds for several classical WSTSs—in particular lossy channel systems (CI-119, CI-24) and monotonic counter machines (CI-126)—and for some richer systems like timed-arc nets (CI-56).
- Establishing complexity lower bounds requires new reduction techniques. Following on our early success with lossy channel systems, we developed coding techniques for simulating ordinal-recursive computations in WSTSs in a robust way, i.e., with encodings that are compatible with the wqo. The versatility of these techniques is high and we could use them to prove very high lower bounds for a variety of systems: reset nets (CI-176), lossy channels (CI-24), timed-arc nets (CI-56), priority channels (Ra-6), etc.
- In parallel, we introduced and analyzed Regular Post Embedding problems. These can be seen as abstract, hence more manageable, versions of systems with lossy channels (CI-167, CI-181, CI-51, CI-39, CI-24). This is an initial step towards our goal of developing a rich array of complete problems for ordinal-recursive complexity classes (see project).

Objective 3 Algorithmics of Counter Systems

Although the study of counter systems (aka register machines) dates back to the '60s, this line of research was mostly about the theory of computability, with Minsky machines being a prominent example of a minimalistic universal model of computation. Our take with counter systems is rather to study their algorithmics, which finds numerous applications, not only for the verification of counter systems themselves (which can be seen as a particular class of programs manipulating integer variables), but also for questions about various logical frameworks (data, spatial, interval, relevance, linear, etc.)

In this regard, WSTS theory offers generic algorithms for *monotone* counter systems, and the complexity analyses of Objective 2 apply. Nevertheless, these bounds are not always optimal, and they simply do not apply to non-monotone models like VAS with hierarchical zero-tests. A finer, and often difficult analysis, that takes the specifics of the model into account, is then required.

In the last five years, we have investigated the algorithmic complexity of counter systems along several tracks:

properties: we have considered large classes of "coverability-like" properties and established their EXPSPACE-completeness on Petri nets and vector addition systems (VAS) (CI-106, RI-2),

extensions: we have worked on VAS extensions, for instance branching VAS (CI-188, RI-44), affine nets (CI-27), or VAS with a single zero-test (CI-203, CI-108, CI-97, RI-13), or

restrictions: on the contrary, we have investigated restrictions on counter systems that lead to decidability and lower complexities, like reversal-boundedness (CI-282) or flatness (RI-65, CI-55), and

memory: we have considered the model-checking problem for logics with a *freeze* operator (CI-197, RI-90, RI-27).

Objective 4 Games

We study games for *synthesis*, where the objective is to automatically synthesize an implementation that realizes a given specification. The synthesis question naturally reduces to game solving. We developed a quantitative theory of design and synthesis that includes several aspects in the specification, such as resource consumption, stochastic behaviors, and partial observation. We proposed several extensions of games and automata and studied their expressiveness and complexity. The main results have been obtained in:

- **quantitative games**, where we solved algorithmic questions for games with combinations of classical (Boolean) winning condition and quantitative winning conditions; the main results settled the complexity of mean-payoff parity games in NP $\cap$coNP, and the complexity of multi-dimensional energy and mean-payoff games as being coNP-complete;
- **quantitative specifications**, where we developed quantitative languages that enjoy both positive closure properties as well as decidability, which makes them appealing to specification-based design with quantitative constraints such as energy consumption; the main result is the new class of mean-payoff automata expressions, and the decidability of all interesting verification problems for them;
- **stochastic and partial-observation games**, where we consider various combinations of stochasticity, partial-observation, and quantitative objectives in games on graphs, useful to get algorithmic solutions of the synthesis problem. The main results show that Markov decision process with mean-payoff parity objectives can be solved in polynomial time, we give the complete picture of tight memory and complexity bounds for qualitative objectives in Markov decision process with partial observation, and we present striking results about partial-observation stochastic games with reachability objectives, showing surprising non-elementary bounds on the memory needed to win, equivalence of decision problems for pure and randomized strategies, as well as unexpected connections of such games with counter systems.

► Scientific report of axis mexico

The goal of the MExICo research axis, which is at the same time also an INRIA project-team, is ***M**odeling and **Ex**ploitation of **I**nteraction and **Co**ncurrency*. Our work consists in developing, exploring and exploiting adequate mathematical models to capture interaction and concurrency, and to develop these theoretical tools and results into effective and efficient methodologies for designing, verifying and monitoring distributed systems.

The problems addressed by MExICo being transversal to many domains, our work involves several application fields; in particular, we currently participate in the EU FP7 Project UNIVERSELF on autonomous telecommunications networks, and the HYCON2 Network of Excellence on *Highly-complex and networked control systems*. Other topics include web service composition security.

Objective 1 Automata and Logics

While automata models can be considered the core of system modeling and semantics, extensions and networked compositions are necessary to address complex systems and tasks.

MExICo has introduced weighted versions of MSO and CTL, which generalize both the boolean logics and their probabilistic counterpart. The use of weights from semirings allows us to incorporate further types of quantities such as energies or rewards, in addition to durations or probabilities, into automata models, and their extensions to pebble automata. Our results include a probabilistic Kleene theorem and find applications in XML query evaluation, which involves navigation for trees. Other extensions of MSO developed by MExICo concern languages over infinite alphabets. We have obtained decidability of MSO model checking of pushdown automata with registers and, more generally, logical and automata-theoretic frameworks for data words.

For *recursive* concurrent systems, we have developed an adequately powerful framework (concurrent visibly pushdown automata) and specification language, and shown that satisfiability and model checking are decidable in doubly exponential time.

A method for distributed synthesis in a natural framework with asynchronously communicating processes has been developed by Nathalie Sznajder, Paul Gastin *et al.* These works show that the distributed synthesis problem is decidable under mild assumption on the communication architectures, and may open the way to a decidable theory of distributed synthesis.

Objective 2 Partial Order Semantics

Occurrence nets, and the underlying (labeled) event structures, are well known partial order models for the concurrent behavior of Petri nets, which is given in the form of partially ordered runs rather than a collection of interleavings. In MExICo, these models constitute important instruments for verification (in particular via the MOLE tool that interfaces e.g. with model checkers). We have also extended ioco-style conformance relations to this partial order framework, and are currently pursuing the development of a *testing* methodology to check conformance of a concurrent implementation with respect to partial order specifications.

On top of the partial order and conflict relations in event structure,s we have introduced the *reveals relation* between events in occurrence nets. Essentially, event a is said to reveal event b if in any maximal run that contains a, b must also occur, be it before, after, or concurrently with a, and even if a and b are not causally related. In our previous work, was for occurrence nets that represent. However, the upper bound was prohibitive for computing the relation in practice. We have shown the reveals relation to be decidable for unfoldings of safe Petri nets, and to be also computable on a given occurrence net via efficient algorithms. Extending this line of research, we have generalized (RI-1) the reveals

relation to express more general dependencies, involving more than two events, and we introduced the ERL logic to express these dependencies as boolean formulas. A synthesis problem arises naturally: given an ERL formula ϕ, is there a finite occurrence net N such that N describes exactly the dependencies between the events of N? We solve this problem with a synthesis method that requires only two synthesis rules. Building on the extended reveals relation, we have recently developed an effective (PSPACE) methodology for *weak* diagnosis of faults : our method allows to detect, from a partial observation of concurrent behavior, whether or not an unobservable *fault* transition inevitably occurs—in the past of the observations, their future, or without causal relation.

Contextual nets are an extension of Petri nets that faithfully models concurrent read accesses to shared resources: such reads are independent and concurrent. Moreover, the unfolding of a contextual net may be up to exponentially smaller than for its non-contextual version. Our work on the theoretical foundations, as well as appropriate data structures and algorithms, has shown the practical efficiency of this approach (which was far from obvious before), and has resulted in an efficient tool, CUNF. Recently, we have made further steps towards improving this approach by investigating merged processes, a data structure that handles choices more efficiently than unfoldings. The implementation of this approach is currently under way.

Objective 3 Timed Systems

In concurrent and composite systems, the real time behavior is of even greater importance than in sequential, centralized ones, but also harder to apprehend. MExICo participates in several research efforts in this area, in particular the ANR project IMPRO on implementability and robustness of real-time systems.

The interplay of concurrency and timing behavior is one of the major research interests of MExICo. We have studied in particular

1. the relations between networks of timed automata on the one hand and time Petri net on the other, giving a concurrency-preserving translation between these models;
2. conditions under which the components in a network of timed automata can evolve *without* sharing the clocks between components, i.e. without the need for one component to read those of another; and
3. a constructive equivalence of Event Clock Message Passing Automata, a model extending the Event Clock Automata of Alur *et al.*

Objective 4 Stochastic Systems

The uncertainty present in concurrent real-time systems often calls for a probabilistic treatment; in the following, we select two of our contributions, to highlight the relevance of probabilistic models in our work.

We have designed a logic HASL for stochastic systems that can express elaborated performance indices related to path behaviours, and developed a tool COSMOS for statistical model checking for HASL formulas over a stochastic Petri net with general distributions. In parallel, we have developed the first importance sampling method for rare events that still produces a confidence interval (rather than an estimated value), and integrated this method in COSMOS.

In joint work with LIAFA, we have solved most of the open problems concerning *product-form Petri nets*. We have provided a sound and complete set of rules to synthesise product form Petri nets, characterized the complexity class of standard problems (liveness, reachability and coverability), and proposed a large subclass of product form Petri nets for which the crucial normalising constant can be efficiently computed. This paper has obtained the outstanding paper award of the ATPN 2011 conference (CI-129).

Currently we are investigating diagnosis and opacity issues in stochastic networks, which are issues we intend to pursue in-depth in the future.

► Scientific report of axis secsi

The SECSI research axis, also an INRIA project-team, is concerned about *security of information systems*. The aim of the SECSI axis is to *develop logic-based verification techniques for security properties of computer systems and networks*. It concentrates on designing automated proof techniques to establish security properties of cryptographic protocols and implementations. It generally aims at applying logic to make our systems and networks more secure, in particular in the area of intrusion detection.

Objective 1 Symbolic verification of cryptographic protocols

In 2008, most security properties that one could check were *trace* properties (secrecy, authentication, typically). This left out many important properties which can only be specified through observational equivalence of processes: e.g., vote-privacy, receipt-freeness and coercion-resistance in e-voting, fairness in contract signing. We started to explore decision procedures for static equivalence first (security against passive adversaries, roughly) (CI-224, CI-245, RI-37, RI-43, RI-10), modulo a large class of equational theories; we have also obtained theory combination results (CI-208). We then moved to observational equivalence (active adversaries) (RI-94), obtaining NP decision procedures (CI-236). The particular challenge of e-voting protocols also spurred the exploration of refined criteria and algorithms for observational equivalence (CI-183, TH-5). On the latter topic, we also studied the question in the presence of so-called group equational theories (CI-54), or with replication (Ra-7). We have also obtained algorithms for the related notion of trace equivalence (CI-90, CI-71, CI-22). Those algorithms have been implemented in dedicated tools (e.g. AKISS and APTE[2]), or integrated in Bruno Blanchet's ProVerif tool. They have been tested on e-voting protocols and on several versions of the electronic passport protocol.

Another concern that was addressed in the SECSI axis is *composition*, i.e., typically, whether putting two secure protocols in parallel is still a secure system. (This is wrong in general.) We designed sufficient conditions that offer such guarantees, even when some long-term keys are shared between the protocols (RI-125, CI-184, CI-266), or when a user chooses the same password for different applications (CI-298, CI-81). This also led us to propose and prove sound some prudent engineering practices that are easily implementable

[2] http://projects.lsv.ens-cachan.fr/APTE/

by protocol designers. We have extended this to composition with sharing of secrets in (CI-52), in an observational equivalence setting, and we have applied it to the ICAO electronic passport standard.

We also addressed the question of producing formal security proofs in a proof assistant such as Coq, as is required more and more often. Instead of writing them by hand, which is tedious, one can instead have them produced automatically by an instrumented model-checker, as described in (CI-301, RI-70).

Objective 2 Computational models

The standard models of security in cryptography are *computational*: messages are actual bit strings, and adversaries and randomized polynomial time machines which communicate on shared tapes. Arguably, computational models are more *faithful* to actual implementations of cryptography than symbolic models (even with equational theories); but computational security proofs are less easily automated.

In this field, we have pursued the path of *computational soundness* theorems. Such theorems state that, under some assumptions, any protocol that is secure in a given symbolic model is also secure in a computational model: we obtain the best of both worlds. See (RI-91) for a state-of-the-art report on symbolic methods for obtaining computational proofs.

We have produced general frameworks (RI-120) for comparing symbolic and computational models. Contrarily to other work on the topic, the set of cryptographic primitives is not fixed, and is a tunable parameter (exclusive-or, ciphers, lists, symmetric encryption, modular exponentiation are examples); an extension is needed, and obtained, for bilinear pairings (RI-71). The soundness theorems we obtained apply to the cases of passive and adaptive adversaries.

The situation with *active* adversaries is more complex. Previous work only considered soundness results relying on trace mappings, which failed to account for indistinguishability (observable equivalence) properties. We have obtained the first computational soundness result for *observational equivalence* (CI-269). This had been an open problem for several years.

Objective 3 Applications (e-voting, security of APIs, circuits)

General verification techniques should be complemented with actual, specific applications. We have looked at a number of important classes of cryptographic protocols and implementations.

First and foremost, we have examined the hot question of verifying *e-voting* systems. The relevant security properties there are numerous, subtle, and hard to define formally and to verify (fairness, eligibility, vote privacy, individual and universal verifiability, coercion resistance, etc.). They justified a good deal of the research presented in previous subsections. We gave the first symbolic definitions for these properties, and analyzed several electronic voting protocols (Ch-11). Verifiability was dealt with in (CI-164), with applications to the FOO'92, Helios 2.0 and JCJ/Civitas protocols. Importantly, our approach highlights the exact parts of the voting system that need to be trusted in order to achieve the properties.

We have also looked at *cryptographic APIs*, such as RSA's PKCS#11, a widely used API used in hardware security modules (HSM) USB security tokens, and smartcards. We managed to overcome the problem of modeling mutable global state, previously identified as a barrier to such a project[3], and found several previously unknown attacks on the standard (CI-299). Further work led to results on proprietary variations (RI-69), and abstraction results permitting security proofs for unbounded fresh keys (CI-226). The model developed in this work is the basis of the Tookan tool[4], which reverse-engineers the configuration of the device under test, builds a model for a model checker, and executes any attack trace found by the model checker directly on the device. Testing on 18 commercially available devices led to the discovery of 10 previously unknown attacks (CI-151). Licenses were sold to Boeing, Barclays, HSBC. Related work included investigating the security of the YubiKey hardware device (CI-40). We also managed to make Bleichenbacher's "million message attack" practical on the RSA PKCS#1v1.5 standard for public key encryption, as used in TLS/SSL for example (CI-44). This led to widespread interest, as one can judge from articles in the New York Times, Boston Globe and Süddeutscher Zeitung.

Objective 4 Protection of hosts and networks

There is more to computer security than cryptographic protocols, APIs, and implementations. We have recognized (since 2001) that we could have some impact in other fields of computer security, and in particular in *intrusion detection*. Our intrusion detection tool ORCHIDS is based on a remarkably efficient, on-the-fly model-checking algorithm for detecting subsequences of events that satisfy some possibly complex

[3] Herzog, J., *Applying protocol analysis to security device interfaces*, IEEE Security & Privacy Magazine, 2006:4(4),pp. 84–87
[4] TOOl for cryptoKi ANalysis, `http://secgroup.ext.dsi.unive.it/tookan/`

formulae. See (IN-23), which explains the kind of mischievous attacks ORCHIDS is able to detect, explains the basic algorithm, several of the important optimizations, and gives a formal proof of its correctness and optimality. There is slow-growing community of users of ORCHIDS, mostly in France (DGA, Bertin, Thalès, EADS, ANSSI) and in Canada (UQàM). ORCHIDS is open-source. LSV serves as the maintainer, and moderator of this open-source community. We have started a program in collaboration with, and funded by the French Direction Générale de l'Armement (DGA) in 2013, to evaluate, improve and document ORCHIDS.

Objective 5 Foundations for probabilistic and non-deterministic choice

Most actual cryptographic protocols rely on coin-flipping, and the semantics of processes should in all generality include provisions for probabilistic choice. Attackers on the other hand cannot be predicted, even probabilistically, and are best modeled as some form of non-deterministic choice. We have looked at the foundational question of finding good denotational models for *mixed* choice, i.e., both probabilistic and non-deterministic choice together, on infinite domains. We looked at simulations between mixed-choice transition systems (an infinite-state generalization of Markov Decision Processes), and generalized this to *similarity measures*, which quantify how far one system is from simulating another one (CI-313). We applied a measure-theoretic variant of this theory to the static analysis of numerical programs that read imprecise data from physical sensors (CI-1, RI-40).

This research led to other advances, some theoretical: a topological duality between angelic and demonic non-determinism (RI-92), a drastically simplified proof of a vast generalization of so-called Choquet-Kendall-Matheron theorems (RI-55), a short proof of a remarkable theorem by Schröder and Simpson, the invention of QRB-domains and the result that they are stable under the probabilistic powerdomain monad (CI-185, RI-16), and a new construction of so-called continuous random variables (CI-127). All this relies on fairly deep results of topology that one could find from various, sparse sources; the book (LI-1) collects them, and then some more, and is meant to become a classical reference. Another outgrowth of the theory, based on our discovery of new results in the field of Noetherian spaces, led us to solve long open problems in the theory of well-structured transition systems (WSTS; see report on the Infini axis): adequate completions of their state spaces (CI-262), natural extensions of the Karp-Miller coverability tree procedure (CI-239, RI-29, IN-5). The invited talk (IN-13) served to explain the basic theory, and how it could be used to solve easily some decidability questions on transition systems beyond the class of WSTS.

► Scientific report of axis tempo

Objective 1 Quantitative verification

Robustness of timed systems. Standard model-checking and synthesis algorithms assume the real system behaves perfectly as specified by the (mathematical) model (e.g. the timed automaton). In particular it assumes there is no perturbations in the system. However if the system runs in a digital environment (for instance if implemented on a digital processor), or if the system controls some physical equipments, this will unlikely be the case: the analysis made on the model will hardly be transferable to the real system.

With that transfer in mind, we have developed a theory for the robustness of timed systems. The first approach consists in over-approximating the system's behaviours by enlarging the clock constraints in the automaton, and to either verify that all behaviours in the enlarged system are correct (which will then ensure that any approximated behaviour, or the implemented behaviour, will be correct), or to synthesize a controller that will guide the system and try to compensate for perturbations. The second approach consists in anticipating imprecisions in the system's behaviour (by shrinking clock constraints accordingly) to prevent for additional behaviours in the system, and to either verify that no important behaviour is lost after shrinking, or to guide the system in such a way that it never gets blocked.

These works have been published as (CI-309, CI-112, CI-99, CI-98, CI-84, IN-8, CI-50). Several journal papers are submitted. The thesis of Ocan Sankur, defended on May 24, 2013, was on that topic.

Timed automata with stochastic aspects. Many applications, *e.g.* communication protocols, require models which integrate both real-time constraints and randomized aspects. The development of such models and corresponding verification algorithms is a challenging task, since it requires combining techniques from both fields of real-time verification and probabilistic verification.

In this context our contribution is the definition of the model of stochastic timed automata and game-extensions thereof, in which both delays and discrete choices can be randomized, and the development of algorithms for their qualitative and quantitative analysis, when this is possible. We distinguish mostly two subclasses of systems for which such algorithms can be designed, the class of single-clock automata, and the class of reactive timed automata, in which no invariant can block time elapsing.

These works have been published as (CI-293, CI-271, CI-231, CI-33), and a journal paper is under submission.

Timed automata with other quantitative aspects. Time is not the only quantity of interest when modelling reactive systems: energy and other resources often have a key role when evaluating the correctness or performances of such systems. Timed automata *with observers* (a.k.a. *weighted* or *priced* timed automata) provide a way of measuring quantities during executions, and with decidable optimisation problems.

As their name indicates, observers do not play any role in the evolution of the model: they can only be used to measure quantities. We have lifted this approach to *energy constraints*, where the only valid executions are those along which the measured quantities remain within given bounds. This is one step closer to hybrid automata, but we proved that timed automata with energy constraints remain decidable when only lower-bound constraints are imposed. On the contrary, reachability becomes undecidable when both lower and upper bounds are enforced.

These results were presented as (CI-273, CI-194, CI-34), and a survey about timed automata with observers was published in Communications of the ACM (RI-49).

Parameter synthesis for hybrid automata. While traditional approaches to parameter synthesis of hybrid automata are based on the analysis of bad states or failure traces, a complementary or *inverse* method has been proposed. It uses a parameter instantiation that is known to guarantee a good behavior in order to derive a constraint on the parameters that leads to the same behavior. There are different scenarios for the application of the inverse method. If a given parameter instantiation is known to guarantee certain properties, the inverse method can be used to derive an enlarged area of the parameter space that preserves these properties, while possibly allowing for enhanced performance of the system. The inverse method can also be used to obtain a measure of coverage of the parameter space by computing the zones of equivalent behavior for each point. This approach is also known as *behavioral cartography*.

The presented algorithms have been implemented in a tool called IMITATOR (Inverse Method for Inferring Time AbstracT behaviOR). The tool has originally been developed for the analysis of timed automata. The new version HYMITATOR implements the semantics of linear hybrid automata. The manipulation of symbolic states is based on the polyhedral operations of the Parma Polyhedra Library.

Various examples, both from the literature and from the industry, have been performed.

In particular, we have performed parametric verification of abstractions of a memory circuit sold by the chipset manufacturer STMicroelectronics, as well as of the prospective flight control system of the next generation of spacecrafts designed by ASTRIUM Space Transportation.

Objective 2 Games for synthesis

Temporal logics for non-zero-sum games. Temporal logics have proven to be a convenient and powerful tool for reasoning about reactive systems, in particular in the framework of model checking. In order to take the interactions of several agents in the evolution of a complex reactive system, temporal logics have been extended with a way to specify how several agents can cooperate in order to achieve their goals. This framework is conveniently seen through an analogy with games, where the agents are players, what they can do forms the rules of the game, and what they want to achieve is their winning objective.

We defined a temporal logic for expressing rich properties of non-zero-sum games (for instance, equilibria properties, or interactions between a server and several clients), and developed algorithms for verifying such properties. These results have been published as conference papers (CI-263, CI-147, CI-37).

Distributed strategy synthesis under imperfect information. Automated synthesis of systems that are correct by construction has been a long-standing ambition of computer science. One major challenge consists in constructing complex systems out of individual components that act locally, without access to full information about the global system. In general, synthesis problems in such distributed settings are undecidable, and one needs additional assumptions about the information flow between components to obtain tractable instances.

We established generic methods for monitoring the flow of information in infinite systems, and studied conditions under which monitors can be abstracted into finite-state automata, to make them accessible to automated synthesis procedures. Another line of research is concerned with distributed strategies in systems with no centralised coordinator. Towards this, we studied coordination problems in games of infinite duration under individual rationality assumptions, such as avoidance of dominated strategies.

Results of this work have been presented in a journal article (RI-76), and as conference papers (Ch-10, CI-79)

Algorithmics for parity games. Parity games are a fundamental model for modeling and analysing discrete reactive systems. Thus, the complexity of solution procedures have a strong impact on automated verification and synthesis.

We studied the complexity of parity games from different perspectives. On the one hand, we identified graph connectivity parameters correlated with algorithmic complexity, leading to the notions of DAG width and entanglement of directed graphs. Bounding these parameters allows to solve the parity game problem efficiently. A second direction of research has been concerned with extensions to the classical model of parity games with perfect information. We developed algorithms for constructing winning strategies in games with imperfect information games, or with quantitative attributes such as counters or registers allowing affine transformations.

Results of this work have been published as conference papers (CI-260, CI-45), and as articles (RI-75, RI-32, RI-17, RI-18, RI-18, CI-273).

3 Implication de l'unité dans la formation par la recherche

- **Master Parisien de Recherche en Informatique (MPRI).** Paul Gastin (2008-2010) puis Hubert Comon (2010-2013) ont été directeurs du MPRI, qui est le principal Master d'Informatique fondamentale sur la région parisienne, co-habilité par l'ENS Cachan, l'ENS Paris, l'Ecole Polytechnique, et l'Université Paris Diderot, en convention avec les Universités Paris 6, Paris 11, Telecom Paristech et INRIA. En s'appuyant sur une équipe pédagogique regroupant environ 130 chercheurs, le MPRI offre une cinquantaine de cours couvrant les principaux domaines de l'informatique fondamentale. Les membres du LSV sont très fortement impliqués dans les enseignements du MPRI.

- **Ecoles d'été et formations à l'étranger.** Les membres du laboratoire se sont impliqués dans de nombreuses écoles internationales et formations à l'étranger dont nous citons ici les principales :
  - Dans le cadre d'une coopération Erasmus avec la Roumanie, D. Berwanger a donné un cours de 48 heures au SNS Bucuresti en mars 2010, S. Haar un cours de 6 heures au Politechnica Bucuresti en mai 2013, et D. Baelde un cours de 8 heures à l'Universitatea Iasi en juin 2013.
  - D. Berwanger, en tant que membre du comité de pilotage de GAMES, a participé à l'organisation de 3 écoles thématiques sur les Automates et les Jeux (Bertinoro, Italie en juin 2009 ; Bordeaux en mai 2011 ; Champéry, Suisse en février 2013).
  - T. Chatain, S. Haar et S. Schwoon sont intervenus dans l'Advanced Tutorial on Unfoldings, associé à la conférence Petri Nets en juin 2012 à Hambourg, et juin 2013 à Milan.
  - H. Comon-Lundh a organisé deux écoles de printemps appelées *CosyProofs* (Computational and Symbolic Proofs of Security) en avril 2009 à Tokyo et en avril 2010 à Barbizon, dans le cadre d'une collaboration franco-japonaise JST/CNRS ; il a également donné un tutorial de 3 heures (« *Logic In Computer Security* ») à la conférence LICS à New Orleans en juin 2013.
  - S. Delaune et S. Kremer ont donné des cours à une école d'été sur le vote électronique SecVote en septembre 2010 à Bertinoro (Italie).
  - S. Demri a donné un cours à l'école d'été ESSLLI (European Summer School In Logic Language and Information) à Copenhague en août 2010, ainsi que P. Schnoebelen et S. Schmitz à l'école ESSLI 2012 à Opole, Pologne.
  - P. Gastin, dans le cadre du projet franco-indien ARCUS, a co-organisé les écoles ACTS'09, ACTS'10 et ACTS'11 (Automata, Concurrency and Timed Systems), et a donné deux exposés de formation à la recherche pour WATA'10 (Weighted Automata : Theory and Applications) en mai 2010, dans le cadre du Research Training Group « *Quantitative Logics and Automata* », à Leipzig en avril 2013.

- S. Haddad a donné deux conférences à l'Advanced Course in Petri Nets (Rostock, septembre 2010), deux conférences à la PhD School du projet européen DISC (Cagliari, juin 2011) et deux conférences aux tutoriaux de la conférence Petri Nets (Hambourg, juin 2012 et Milan, juin 2013).
- L. Ségoufin, dans le cadre du projet européen FoX, a co-organisé deux écoles (5-9 oct 2009 à Dortmund, 1-3 sept 2010 à Varsovie), et a assuré un cours de 3h à l'école organisée par GAMES les 4-8 février 2013 à Champéry (Suisse).

- **Laboratoire International Associé (LIA) *INFORMEL*.** Paul Gastin est co-directeur du LIA franco-indien *INFORMEL*, avec Madhavan Mukund (CMI). Le laboratoire, fondé en 2012, fédère les activités de chercheurs du CNRS, de l'ENS Cachan de l'Université Bordeaux 1, côté français, et le Chennai Mathematical Institue (CMI), l'Institute of Mathematical Sciences Chennai (IMSc), et l'Indian Insitute od Science Bangalore (IISc), côté indien. La thématique couvre les méthodes formelles et leurs applications à la vérification des systèmes complexes. Le LIA a déjà permis de financer le stage de 3 mois de 4 étudiants indiens (CMI et IIT Bombay) en France de mai à juillet 2012, ainsi que la thèse d'un doctorant indien en co-tutelle avec Philippe Schnoebelen (LSV) et K. Narayan Kumar (CMI) depuis octobre 2012. Il a également permis d'initier des collaborations entre membres du LSV et chercheurs indiens qui ont déjà abouti aux publications communes (CI-36, CI-51).

- **Institut FARMAN.** Laurent Fribourg est directeur scientifique de l'Institut Farman qui fédère et soutient des projets inter-disciplinaires de 5 labos de l'ENS Cachan (maths appliquées, électronique, automatique, mécanique et informatique). Durant la période 2008-2013, le LSV a participé à 8 projets Farman dont 4 ont donné lieu à des publications communes avec les labos de mécanique, électronique ou automatique dans des conférences internationales (CI-68, CI-91, CO-20, RI-87). En outre, le laboratoire SATIE (électronique) en coopération avec le LSV va organiser une formation à Cachan en 2014 à destination des industriels de l'automobile et de l'électronique de puissance sur la synthèse de commande des systèmes commutés. En 2008-2013, à travers Farman, le LSV a ainsi contribué significativement à l'essor de l'inter-disciplinarité sur le campus de Cachan et à la diffusion de l'utilisation des méthodes formelles auprès de nos collègues des Sciences Pour l'Ingénieur.

4 Stratégie et perspectives scientifiques pour le futur contrat

4.1 Points forts (éléments qui soutiennent la stratégie scientifique)

- **Excellence scientifique.** L'excellence scientifique qui se traduit par des centaines de publications dans les meilleurs journaux et actes de conférences internationales, qui était déjà un de nos points forts à la dernière évaluation, s'est maintenue et même renforcée.

- **Animation scientifique.** En même temps, l'implication des membres du LSV dans l'animation et les instances d'évaluation et de pilotage de la recherche scientifique, déjà importante au dernier quadriennal, s'est considérablement accrue (dizaines d'organisation et/ou présidences d'événements internationaux, dizaines de participations à des comités AERES, deux appartenances au CoNRS, appartenances aux instances de l'INRIA). La visibilité et reconnaissance internationale se sont également spectaculairement manifestées par l'octroi de deux médailles d'argent CNRS en 2008 et 2011, un prix international EATCS Presburger 2011, un ERC starting grant 2012 et plusieurs contrats européens FP7.

- **Liens avec INRIA.** L'arrivée de Serge Abiteboul dans l'axe DAHU en 2008 a conféré, non seulement au LSV, mais également à l'ENS Cachan une visibilité mondiale, notamment lors de son cours assuré au Collège de France en 2012 (« Sciences des données : de la logique du premier ordre à la Toile »). Le partenariat avec INRIA s'est renforcé avec la création d'une 3ème équipe-projet MEXICO en 2009 sur la vérification et synthèse des architectures distribuées. De façon générale, INRIA propose des bourses de doctorants et post-doctorants qui permettent un flux des élèves de l'ENS cachan et du MPRI vers les equipes INRIA externes à Cachan, et en sens inverse, de financer des doctorats, post-docs et délégations. L'étape suivante naturelle est que INRIA devienne la 3ème co-tutelle du LSV (en sus du CNRS et de l'ENS cachan). Le processus n'a pas encore abouti pour des raisons de calendrier, mais devrait être conclu en 2014.

- **LIA INFORMEL.** En dehors du renforcement des liens avec l'INRIA, la création du LIA INFORMEL avec l'Inde et l'essor de l'Institut Farman de l'ENS cachan ont eu un grand impact sur la vie du laboratoire. Le LIA INFORMEL a été à l'origine d'un très important flux de visiteurs (professeurs, doctorants, post-doctorants) indiens au lSV et, en sens inverse, de visites longues de plusieurs mois de chercheurs du

LSV (Paul Gastin, Dietmar Berwanger,. . .) en Inde, ce qui a abouti à des coopérations très fructueuses notamment dans le domaine des jeux et systèmes distribués.

- **Institut Farman.** L'Institut Farman a permis, quant à lui, au travers d'une dizaine de projets interdisciplinaires, de faire collaborer des membres du LSV avec des membres de laboratoires d'électronique, d'automatique et de mécanique de l'ENS Cachan sur des thématiques nouvelles pour le LSV, et a permis de faire connaître l'intérêt des méthodes formelles au-delà du cercle des informaticiens.

- **Cohésion du laboratoire.** D'un point de vue organisationnel, la dispersion des membres du LSV sur quatre sites résultant de la croissance des effectifs lors de la période 2005-2008 a pris fin grâce à d'importants travaux qui ont abouti à la fusion de trois de ces sites. Notons au passage que le mode de fonctionnement et la cohésion du laboratoire se sont parfaitement maintenus durant la période 2008-2013 malgré un changement de direction en 2011. Nous en sommes redevables au type d'organisation proche et réparti mis en place dès la création, à l'esprit collectif de tous les membres, et à l'excellence du personnel ITA, en particulier de la gestionnaire du laboratoire depuis 2008.

4.2 Points à améliorer (éléments internes qui pourraient fragiliser la stratégie scientifique ou ls perspectives)

- **Encadrement.** Nous éprouvons de façon récurrente une difficulté à recruter des doctorants. Ceci est un problème général en France où les jeunes ont tendance à se détourner de la recherche scientifique. Notons que nous avons pour règle de ne pas recruter plus d'un ou deux doctorants issus de l'ENS Cachan par année.

4.3 Risques liés au contexte (éléments externes de nature à contrarier la stratégie scientifique)

- **Contacts industriels.** Après le départ de Graham Steel qui a joué un rôle moteur dans les contacts avec les industriels sur la période 2008-2012, il y a un risque certain de démobilisation du LSV vis-à-vis des contrats industriels. Ces contrats nécessitent souvent une grande énergie des chercheurs, et se heurtent à la pression exercée par les industriels sur leurs ingénieurs pour avoir des résultats en des temps trop courts de réflexion et d'échange. Nous explorons actuellement la possibilité de mutualiser ces relations industrielles au sein de l'Institut Farman en nous associant avec d'autres laboratoires de l'Institut qui semblent avoir une meilleure expérience et gestion des contrats industriels.

- **Déménagement sur le plateau de Saclay.** Le déménagement de l'ENS cachan sur le campus Paris-Saclay en 2018 est évidemment un facteur de risques. Ces risques sont multiples :
  - éloignement de Paris, carence des transports, carence des logements étudiants, difficultés conséquentes de faire venir et loger des professeurs invités ;
  - distension de nos liens avec les universités parisiennes ;
  - concurrence, partage et appauvrissement des ressources face à des disciplines mieux reconnues sur le plateau (comme les physiciens), . . .

La décision de déménagement, à laquelle le LSV n'a évidemment pris aucune part, étant actée, beaucoup d'entre nous se sont considérablement investis depuis deux ans dans les actions associées, notamment dans les multiples initiatives d'excellence (Idex, Labex, Equipex,. . .) :

- Sege Abiteboul a fait partie dès son origine du « CAC » (ancêtre du Sénat Académique), puis fait partie aujourd'hui du Sénat,

- Hubert Comon a été à l'initiative d'un premier projet de Labex, et est responsable de la commission formation de l'actuel labex Digicosme,

- Philippe Schnoebelen est responsable d'un des 3 axes scientifiques du labex Digicosme (axe SciLex : « Sûreté/Sécurité »).

En résumé, nous nous investissons, avec nos collègues du LRI, du LIX et autres laboratoires d'informatique du campus Paris-Saclay, pour faire reconnaître la discipline informatique (dénommée STIC) au travers d'un département et d'une Ecole Doctorale *unique*. Notre action se joue, non seulement au niveau institutionnel pour délimiter le périmètre de l'informatique et ses interfaces, mais au niveau scientifique pour recentrer et enrichir les champs scientifiques des laboratoires informatiques du campus. Pour prendre l'exemple de quelques pistes concrètes du LSV, l'installation sur Saclay pourrait être l'occasion de (re)collaborer avec :

- l'équipe de Catuscia Palamidessi (LIX) dans le domaine du pi-calcul probabiliste,
- l'équipe ProVal (LRI) sur la preuve de programmes, ou
- l'équipe d'Eric Goubault (CEA-LIST) sur la simulation symbolique et l'interprétation abstraite.

La prochaine relocalisation sur Saclay nous incite ainsi à monter dès aujourd'hui de nouveaux projets en commun. L'axe SciLex du labex Digicosme fournit un cadre naturel à la définition d'axes stratégiques de coopération. L'avenir des axes scientifiques du LSV est donc lié à l'élaboration des coopérations qui vont se dégager dans les 3 prochaines années.

Tout en explorant ces nouvelles opportunités associées à Saclay, le projet scientifique du LSV reste cependant fondamentalement associé aujourd'hui aux 5 axes actuels. Chaque axe a ainsi développé un projet propre qui s'inscrit dans le prolongement naturel de sa problématique et de ses travaux. Ce sont ces projets propres qui vont être maintenant exposés[5].

4.4 Projet scientifique

► Scientific project of axis dahu

For the next years we would like to distinguish three objectives.

Objective 1 Specification and verification of database driven systems

This objective aims at making systems with data safer and more reliable. This means providing suitable models together with a toolbox for helping in the design and implementation of such systems. It is a continuation of our current work and will be done in collaboration with V. Vianu (UCSD) and M. Bojańczyk (Warsaw). This objective is very broad and has many facets. During the next years we will work in particular on the following questions.

- The results we have recently obtained on the static analysis of the AXML model yields very high complexities that limit its practical impact. In the future we plan to investigate more realistic scenarios.
- We will also continue our work on automated verification of temporal properties over database driven systems. We would like to extend our previous work in order to deal with more general model of databases and include more operations on data.

Objective 2 Query processing for the Web

This objective aims at finding query languages and query processing solutions suitable for modern Web applications. This includes efficient query evaluation as well as query optimization. Besides continuing our work on the analysis of XML query languages, we will investigate two new directions, namely querying Web graph databases and enumeration techniques for query answering.

- *Query languages for graph databases.* Graph-structured data on the Web can be found in emerging applications such as *RDF* and *linked data*, or *social networks*. Classical database languages are not suitable to query such data, essentially because they do not allow to (easily) express simple connectivity queries, which are the basic building block in graph navigation. On the other hand, query languages based on reachability patterns, which have also been extensively studied, do allow graph navigation, but are too limited in the Web scenario. Extensions of these languages which support queries of interest for RDF or social network applications have been recently proposed, but they come with a high evaluation cost. Our main objective here is to study new graph query languages which guarantee efficient query evaluation and feasible optimization, still being sufficiently expressive to define typical interesting queries in the Web application context.
- *Enumeration of query answers.* We plan to continue our work on enumeration of query answers. Recall that the goal is to obtain index structures easily computable (say in linear time in the size of the database), that allow constant delay in the enumeration process. This raises many challenging fundamental questions that we would like to address. For instance we would like to understand when this enumeration process is not possible (lower bounds). We would also like to extend the cases where we already have constant delay enumeration by either considering bigger classes of structures or more powerful logics (upper bounds).

[5] en anglais, à des fins de réutilisation pour les évaluations INRIA des EPC

Objective 3 Distributed knowledge base

As a foundation for managing distribution, we are investigating the use of distributed knowledge bases to handle data and meta-data, as well as access control and localization, in a holistic integrated setting. Reasoning on a knowledge base is specified using a rule-based language supporting the exchange of rules, namely Webdamlog. This raises a number of issues such as scaling to a large number of participants, integrating with popular systems and social networks, and in general helping users with accessing data.

The approach also raises data privacy issues. Access control is well understood in a centralized setting but much less in a distributed one. We are investigating issues related to keeping some control on data access even when data circulate on a network. We also want to control the exchange of rules and the distribution of tasks.

Finally, observe that data on the Web (and in particular in a social network) are typically imprecise and uncertain. We want to investigate issues such as data integration in such a setting. This involves, for instance, understanding the alignment of entities and relations from different sources as well as that of resolving contradictions between the sources.

► Scientific project of axis infini

The main thrust for our investigations in the coming years revolves around the decidability, algorithmics and complexity of WSTS models and of the most commonly used wqos. Let us just mention three kinds of projects (involving WSTS/WQO) among all others:

Objective 1 Algorithmics of Complete WSTS/WQOs

The theory of complete wqos and complete WSTS (CI-262, CI-123, RI-29, IN-5) currently deals mostly with decidability and/or forward analysis. This field is still mostly uncovered (e.g., good data-structures for ideals have only been proposed for the two simplest wqos used in verification). We intend to pursue this topic by exploring in more depth the possibilities that have been opened: complexity of completion-based algorithms, generic data-structures for completion-based algorithms (i.e., for ideals, cones, limits), coverability trees and graphs for complete WSTS.

Objective 2 Regular Model-Checking and Complete WSTS

The completion techniques (and the new well-structured systems) open the way to regular model-checking approaches for the verification of new models. For some of them, e.g. the priority channel systems of (Ra-6), we intend to develop data-structures, acceleration techniques, and finally prototype, tools demonstrating the feasibility of automated verification.

Objective 3 Complexity Beyond Elementary

Our initial results on the complexity of problems that rely on a wqo for decidability have unearthed a surprising gap in complexity theory. When dealing with problems that are non-elementary, i.e., outside the exponential hierarchy, but still decidable, thus also outside the scope of the arithmetic and analytic hierarchies, one has no adequate framework for assessing computational complexity.[6] This is unfortunate since problems of such complexity often appear in combinatorics, logics, and verification. The consequence of this gap is that most of the work for complexity analysis has to start afresh from low-level Turing machine computations, instead of employing simpler reductions from some master problem, like SAT for NP or the Post Correspondence Problem for Σ_1. We intend to develop the adequate notions of complexity classes and reductions, and propose good master problems for such complexities. This foundational effort relates problems from different areas, in particular, problems outside verification. It will require communicating with the experts in those areas if we expect them to start using the newly-proposed complexity tools.

► Scientific project of axis mexico

The results obtained thus far point to several opportunities and leads that will govern our work over the coming years.

[6] Even Aaronson's Complexity Zoo has only Primitive-Recursive between Elementary and Recursive.

Objective 1 Models for concurrency

The study of the key models for concurrent behavior, including communicating automata, Petri nets, their variants and unfoldings, remains at the heart of MExICo's work. Moreover, the testing and diagnosis frameworks for concurrent systems will be further explored. We mention in particular recent work on active diagnosis, i.e. the synthesis of control strategies to ensure diagnosability for systems whose observability properties do not allow diagnosis without control input. For this problem, which combines challenges of diagnosis and of controller synthesis, we have recently developed a novel approach involving advanced automata theoretic constructions. Here, it will be interesting next to treat the case of several fault types, which makes the problem a multi-objective one, to compute precisely and to minimize the exact diagnosis delay; and there are many other perspectives in this direction.

Objective 2 Verification of distributed systems

In a broader view, the questions of *observability* and *opacity* of concurrent systems will be in the focus of our research, in both a logical and a probabilistic perspective. We aim at completing the formal framework for handling interaction and observation in a concurrent, partial order or compositional setting. The role of different types of *fairness* properties, witnessed already by the reveals relations researched in the MExICo team, in designing and monitoring systems, is another issue that deserves further investigation.

Specifications in partial order logics have the potential to capture subtle yet vital properties for distributed systems that involve, e.g., concurrent transactions. The MExICo team has strong expertise in these logics, and contributed to showing that for suitable restrictions of such logics, model checking and satisfiability are decidable. We are interested in pursuing research in this only partly charted territory; in particular, efficient *distributed* verification algorithms have yet to be developed.

Objective 3 Implementability

We have identified the problem of *implementation* on distributed architectures from models like Petri nets or networks of automata that describe concurrency using high-level paradigms such as multi-party rendez-vous or shared clocks. Implementing them, or simply translating them to lower-level models, requires introducing new communications e.g. to initiate a rendez-vous, or send the value of a clock. Yet the implementation should keep as much as possible of the concurrency specified in the high-level model. To tackle this problem, we first need the right tools that allow us to compare behaviours of (possibly heterogeneous) models. Classical preorders like simulation are not sufficient since they compare only sequential behaviours and do not take concurrency into account. Concurrent bisimulations exist but they are limited to fully asynchronous systems without time and without information about the decomposition in sequential components. We will have to design more powerful notions. Then we will define transformations from high-level to low-level models that show how, for each high-level communication paradigm, these can be implemented and how much communication between components they require. These transformations will then have to be validated with respect to the appropriate behavioural comparisons as above.

MExICo's work is driven by formalizable problems that are common to several application domains; we therefore continue to work on several such fields rather than a single one. Contrary to what we expected five years ago, today the field of service composition and orchestration is not fertile for industrial cooperation. However, fruitful contacts exist with telecommunications and public transport operators, in particular via the IRT SystemX in whose subproject on multi-modal transport we are involved. Over the five years to come, these fields will definitely play an important role in our work; we will seek and seize further opportunities where possible.

► Scientific project of axis secsi

Computer security is more pressing a concern as ever, and this is not going to change anytime soon. Attacks were once limited to what an isolated hacker teen did, and are now produced by gangster organizations, big firms, and government agencies alike. New threats are emerging every day, and the incredible variety of application domains of which we have already mentioned a few testifies of it.

SECSI was initially started in 2001 with the ambition of having a global view on computer security. This is no longer possible. We must therefore concentrate on a few important topics, on which we have built expertise, and on which we can hope to have an impact in the future. These topics include continuations of many questions we have addressed in the past.

Objective 1 Symbolic vs. computational models

On the *foundations of cryptographic security*, a common belief is that symbolic models are not faithful to reality, but computational models are. We have shown that there were many bridges between the two, so that symbolic models are, in fact, relatively realistic. More importantly, we have shown that even computational models have severe limitations, as the case of dishonest keys demonstrates. We strongly believe that an entirely novel approach is called for, and the symbolic model proposed in (CI-73), where what is specified is what the attacker cannot do, is certainly the right way. This has to be explored and deepened: completing a catalogue of useful impossibility assumptions, and designing efficient automated proof techniques.

Objective 2 Equivalence-based properties

A second avenue that we will pursue is on *equivalence-based properties*. As we have said already, trace-based security properties have been fairly well studied, but new issues such as *privacy* (in e-voting, the electronic passport, for example) call for entirely new models and algorithmic techniques. We have described some of the first attempts we have done in this direction. Stéphanie DELAUNE's new ANR grant VIP (`http://www.lsv.ens-cachan.fr/Projects/anr-vip/?l=en`), started January 2012, will serve as a driving force here. This covers three aspects. The first one is *models*. Already in e-voting, privacy means several different security properties, and this only gets more complicated with the consideration of other protocols with a privacy aspect: for many applications such as routing protocols or location-based services for vehicular ad hoc networks (e.g. e-toll collection, "pay-as-you-go" insurance, . . .), formal definitions of privacy are still missing. We plan to repair this. The second aspect is *algorithms* for verifying equivalence-based properties: trace versus observational equivalence, more precise approximations (than, e.g., those used in B. Blanchet's ProVerif, which are already too coarse in verifying voter anonymity in e-voting protocols), equivalence for larger classes of processes. Finally, we plan to explore *modularity*, in two directions: *combining* the decision procedures that we will obtain for various cryptographic primitives, and *composing* protocols together, even in the presence of shared secrets. We have already described some of our efforts in these directions. Applications include being able to establish privacy in the presence of two honest voters (not just one, as done now), or untraceability in presence of two different tags; in the longer term, to obtain guarantees in a setting that involves arbitrarily many voters or tags.

Objective 3 Automated proofs

Finally, we would like to explore *new proof techniques*. We have concentrated on automated security proofs, but scalability concerns will inevitably force us to design new approaches that mix automated and interactive proofs. We shall also come back to the question of certification, and the generation of formal proofs of security (in a proof assistant), which (CI-301, RI-70) pioneered in a setting restricted to secrecy, symbolic models, and completely automated formal proof generation. We plan to keep an eye on extensions to probabilistic and non-deterministic systems (on the theoretical side of which we now have considerable expertise), and on the security of implementations (both software and hardware).

► Scientific project of axis tempo

Our research project for the next five years tightly follows the research programme of two European project that the TEMPO group just got accepted: the first one is the ERC project EQualIS "Enhancing the Quality of Interacting Systems", with Patricia Bouyer as principal investigator; the second one is the FET project Cassting "Collective Adaptive System Synthesis using Non-zero-sum Games", with Nicolas Markey as the coordinator. Both projects share a common objective of developing new techniques for reasoning about and automatically synthesising complex systems, including quantitative constraints.

Objective 1 Analysis of complex interacting systems

With the development of both wired and wireless communications, an increasing number of reactive systems are now able to communicate with their surrounding systems, and to take advantage of this information in order to optimise their behaviour. These interactions make the verification process much more complex, as the objective is now to ensure correctness of the whole system for any behaviour of the surrounding systems.

Using a convenient analogy with game theory, we see the surrounding systems as an opponent player, whose role is to adapt their behaviour in order to make the system fail. Checking correctness of the system in this setting corresponds to checking that the system is always able to counteract these attacks of the environment: this precisely corresponds to checking that the system has a winning strategy in the game it plays against the neighbouring devices.

Objective 2 Automated synthesis

The verification process is mostly based on a trial-and-error approach, where a hand-crafted model of a system is checked and refined iteratively until (hopefully) a correct model is obtained. The drawback is obvious, and the automatic synthesis of a model that would be correct by construction would be an unprecedented breakthrough in model-based design.

Here again, game theory will be a convenient formalism, but we have to model each component of the system as a different player, having its own role and objective. The classical zero-sum setting, where two players have opposite objectives, is not powerful enough to model such interactions: when dealing with complex systems where many components interact, we need to move to the much richer setting of *non-zero-sum games*. This in turn requires that we move from the simple concept of winning strategies to more intricate concepts involving equilibria. Understanding what are the relevant concepts in the context of formal verification, and developing models, languages and algorithms for modelling, reasoning about and verifying such systems, are two important challenges that we will meet.

Objective 3 Measures of correctness

While most of verification techniques use boolean values, we believe that defining and evaluating *measures of correctness* of a system would be much more informative than the mere boolean value computed by the current techniques. While we think this is true of classical models (automata, ...) involving no quantitative aspects, this is even more obvious when dealing with quantitative models, such as priced and/or timed automata, and when dealing with robustness of such systems against external perturbations.

5 Bilan récapitulatif

Du 1er janvier 2008 au 30 juin 2013 :

- Les effectifs de l'unité sont passés de 21 chercheurs et enseignants-chercheurs permanents à 24 avec un flux de 7 entrants pour 4 sortants.
- Le LSV a formé 18 doctorants et 8 HDR (dont les 4 sortants).
- Le LSV a créé deux nouveaux axes correspondant à deux nouvelles équipes-projets communes (EPC) avec INRIA, passant ainsi de trois à cinq axes.
- Le LSV a été à l'initiative d'un laboratoire international associé (LIA) du CNRS avec l'Inde.
- Le LSV a contribué de façon significative au développement important de l'Institut Farman (Fédération de Recherche CNRS créée en 2007) qui coordonne les activités interdisciplinaires de cinq laboratoires sur le campus de l'ENS Cachan.
- Les membres du LSV ont écrit sur la période plusieurs centaines de publications dans les revues et actes de conférence les plus prestigieuses du domaine. Ils ont organisé ou présidé 15 conférences internationales sur la période.
- Le LSV a participé à de nombreuses instances d'évaluation et de pilotage de la Recherche (par ex., 22 participations à des comités d'évaluation AERES).
- Plusieurs membres du LSV ont reçu de prestigieuses marques de reconnaissance (par ex., deux médailles d'argent CNRS, un prix EATCS Presburger, un projet ERC Starting Grant, une chaire au Collège de France).
- Afin d'améliorer la pérennisation de ses relations industrielles, le LSV va explorer la possibilité de mutualiser ces relations avec d'autres laboratoires de l'Institut Farman.
- Le projet scientifique du LSV repose sur le socle des cinq projets propres aux axes du laboratoire, et sur l'exploration dès aujourd'hui de coopérations potentielles avec les laboratoires LIX et LRI avec qui nous participons au développement de la science informatique sur le campus de l'Université Paris-Saclay.

agence d'évaluation de la recherche et de l'enseignement supérieur

Annexe 1 :
Présentation synthétique de l'entité

Laboratoire Spécification & Vérification

Intitulé de l'unité : Laboratoire Spécification & Vérification
Nom du directeur d'unité : Laurent Fribourg

▶ Effectifs de l'entité (au début du contrat en cours)

....**8**.... enseignants-chercheurs ; ....**13**... chercheurs ; ....**4**.... techniciens, ingénieurs et autres personnels ; ...**21**... post-docs et doctorants.

▶ Personnels ayant quitté l'entité pendant le contrat en cours

....**6**.... statutaires (..**250**.. mois) ; ...**25**... doctorants (..**664**.. mois) ; ....**13**... post-docs (...**156**.. mois) ;

▶ Nombre de recrutements réalisés au cours de la période considérée et origine des personnels

....**3**.... chercheurs (2 CNRS, 1 INRIA) ; ....**4**.... enseignants-chercheurs (ENS Cachan) ; ....**4**.... ITA (3 CNRS, 1 INRIA) ; ...**23**... doctorants ; ....**13**... post-doctorants.

1 Production scientifique au cours de la période écoulée (1er janvier 2008 – 30 juin 2013)

▶ Résultats majeurs

- **Analyse d'APIs de sécurité.** Par des méthodes de reverse-engineering automatisé et de démonstration automatique, l'outil Tookan a découvert des bugs de sécurité dans des dispositifs PKCS#11 commerciaux (cartes à puce, hardware security modules, tokens de sécurité), et a ainsi mis à jour plus d'une douzaine de nouvelles attaques. Ce travail a fait l'objet d'articles dans le New York Times, le Boston Globe, le Süddeutscher Zeitung.

- **XML avec information incomplète.** Nous avons réalisé une étude systématique de l'information incomplète dans les documents XML en visant à la rendre indépendante de l'application visée. Ceci a permis d'établir des classes de description de l'information incomplète qui sont robustes et débouchent sur des solutions algorithmiques efficaces.

- **Synthèse distribuée pour systèmes à communications asynchrones.** Le problème est de dériver automatiquement un programme pour un système dont toutes les exécutions satisfont une spécification donnée et ce, quelle que soit la façon dont l'environnement se comporte. Dans le cadre des systèmes ayant un comportement asynchrone, nous avons introduit un nouveau modèle de communication par *signaux*. Nous avons montré que, dans ce cadre, le problème de synthèse est décidable pour les systèmes dont le graphe de communication est fortement connexe.

- **Robustesse des systèmes temporisés.** Nous avons proposé une méthode de synthèse des stratégies garantissant l'atteignabilité d'un état-cible pour les automates temporisés, même en présence de petites perturbations induites par l'environnement sur les valeurs nominales des délais des automates.

- **Utilisation du lemme de Dickson pour classifier la complexité des problèmes informatiques.** Nous avons montré que les quasi-ordres bien fondés peuvent être utilisés non seulement pour la preuve de terminaison d'algorithmes, mais aussi pour établir des bornes supérieures de complexité.

► Bilan quantitatif des publications de l'entité

	2008	2009	2010	2011	2012	2013 jan.-juin	Total
ouvrages, chapitres, édition d'actes	7	20	5	12	4	4	52
revues internationales	22	23	40	16	34	12	147
invitations dans des conférences internationales	4	5	5	3	5	1	23
articles dans des conférences internationales	52	61	61	65	53	24	316
thèses de doctorat ou d'habilitation	4	6	6	12	7	2	37

► Publications majeures

(CC08) H. Comon-Lundh and V. Cortier. Computational Soundness of Observational Equivalence. In CCS'08, pages 109-118. ACM Press, 2008.

(ASV09) S. Abiteboul, L. Segoufin and V. Vianu. Static Analysis of Active XML Systems. ACM Transactions on Database Systems 34(4), 2009.

(BFLM11) P. Bouyer, U. Fahrenberg, K. G. Larsen and N. Markey. Quantitative analysis of real-time systems using priced timed automata. Communications of the ACM 54(9), pages 78-87, 2011.

(BHS12) B. Bérard, S. Haddad and M. Sassolas. Interrupt Timed Automata : verification and expressiveness. Formal Methods in System Design 40(1), pages 41-87, 2012.

(CD12) K. Chatterjee and L. Doyen. Partial-Observation Stochastic Games : How to Win when Belief Fails. In LICS'12, pages 175-184. IEEE Computer Society Press, 2012.

► Documents majeurs

- **Tookan** (logiciel) : outil d'analyse automatique de dispositifs de sécurité obéissant à la norme PKCS#11. A découvert plus d'une douzaine de vulnérabilités dans des produits commerciaux. `http://secgroup.ext.dsi.unive.it/tookan/`. Licence propriétaire.

- **Orchids** (logiciel) : outil de détection et de prévention d'intrusions temps réel, efficace, multi-sources. `http://www.lsv.ens-cachan.fr/Software/orchids/v2.1/`. Licence Cecill2 (GPL).

- **Webdamlog** (logiciel) : système d'échange et de manipulation de données distribuées sur le Web, capable de gérer l'hétérogénéïté des applications et services du réseau. `http://hal.inria.fr/hal-00813300`.

- **CosyVerif** (logiciel) : plateforme fournissant l'accès à différents outils de spécification et vérification de systèmes dynamiques. `http://www.cosyverif.org/`. Licence AGPL3 and EPL1.

- **Imitator** (logiciel) : outil de synthèse de contraintes pour modèles paramétrés à base d'automates temporisés, garantissant un comportement équivalent à un comportement de référence. `http://www.lsv.ens-cachan.fr/Software/imitator/`. Licence GPL.

2 Faits illustrant le rayonnement ou l'attractivité académiques de l'entité

- **Distinctions** : chaire « *Informatique et sciences numériques* » du Collège de France attribuée à Serge Abiteboul en 2011.

- **Prix et récompenses** : médailles d'argent du CNRS décernées à Hubert Comon-Lundh (2008) et à Jean Goubault-Larrecq (2011) ; Prix Presburger décerné à Patricia Bouyer-Decitre (2011).

- **Exposés invitatés à des conférences internationales** : FSTTCS'08 (Hubert COMON-LUNDH), ICALP'10 (Jean GOUBAULT-LARRECQ), PetriNets'12 (Alain FINKEL), ICDT'13 (Luc SEGOUFIN).
- **Organisation de colloques** : Computer Security Foundation Symposium (CSF'10, CSF'11) ; Concurrency Theory (CONCUR'10) ; Temporal Representation and Reasoning (TIME'10).
- **Coordination de projets internationaux** : ERC EQualIS (« *Enhancing Quality of Interacting Systems* », Patricia BOUYER-DECITRE), ERC Webdam (« *Web Data Management* », Serge ABITEBOUL), FET FoX (« *Foundations of XML* », Luc SEGOUFIN), FET Cassting (« *Synthesis using Non-zero-sum Games* », Nicolas MARKEY), LIA INFORMEL (« *INdo-French FORmal MEthods Lab.* », Paul GASTIN).

3 Faits illustrant les interactions de l'entité avec son environnement socio-économique ou culturel

- **Nomination** : Serge ABITEBOUL a été nommé membre du Conseil National du Numérique.
- **Contrats industriels** :
  - Certificat APP Tookan en 2011, et contrats INRIA avec Boeing en 2010, Barclays en 2010, HSBC en 2011.
  - Contrat d'étude du LSV pour le cabinet AdviTech Partners en 2009 : étude de faisabilité de la startup SpidWare dans le domaine de la sécurité informatique.
  - Projet blanc CPP (confiance, preuves et probabilités) en 2009-2013 avec LSV (coordinateur), CEA Saclay, INRIA, Supélec, Dassault Systèmes, Hispano-Suiza, Safran (ex. SagemCom).
  - certificat APP Orchids délivré en 2012, suivi d'une convention INRIA-DGA sur Orchids, 2013-2016.
  - Contrat ANR VALMEM avec LSV (coordinateur), LIP6 et STMicroelectronics de 2007 à 2010 ; validation de la mémoire SPSMALL.
  - Accord CIFRE ENS Cachan-EADS : co-encadrement thèse Jean-Loup Carré (2007-2010) et participation au logiciel Penjili (propriétaire EADS) d'analyse statique de code C.
  - Contrats CIFRE avec EDF (thèse d'Arnaud Sangnier en 2008) et France Telecom/Orange (thèse de Camille Vacher en 2010).

4 Contribution à des actions de formation

- Direction du Master Parisien de Recherche en Informatique (Hubert COMON-LUNDH).
- Direction du département d'informatique de l'École Normale Supérieure de Cachan (Paul GASTIN).
- D. Berwanger a donné un cours de 48 heures au SNS Bucuresti en mars 2010 dans le cadre d'une coopération Erasmus avec la Roumanie.
- D. Berwanger a co-organisé trois écoles thématiques sur les Automates et les Jeux (Bertinoro, Italie en juin 2009 ; Bordeaux en mai 2011 ; Champéry, Suisse en février 2013).
- H. Comon-Lundh a organisé deux écoles de printemps appelées *CosyProofs* (Computational and Symbolic Proofs of Security) en avril 2009 à Tokyo et en avril 2010 à Barbizon, dans le cadre d'une collaboration franco-japonaise JST/CNRS.
- P. Gastin, dans le cadre du projet franco-indien ARCUS, a co-organisé les écoles ACTS'09, ACTS'10 et ACTS'11 (Automata, Concurrency and Timed Systems).
- L. Ségoufin, dans le cadre du projet européen FoX, a co-organisé deux écoles (5-9 oct 2009 à Dortmund, 1-3 sept 2010 à Varsovie).

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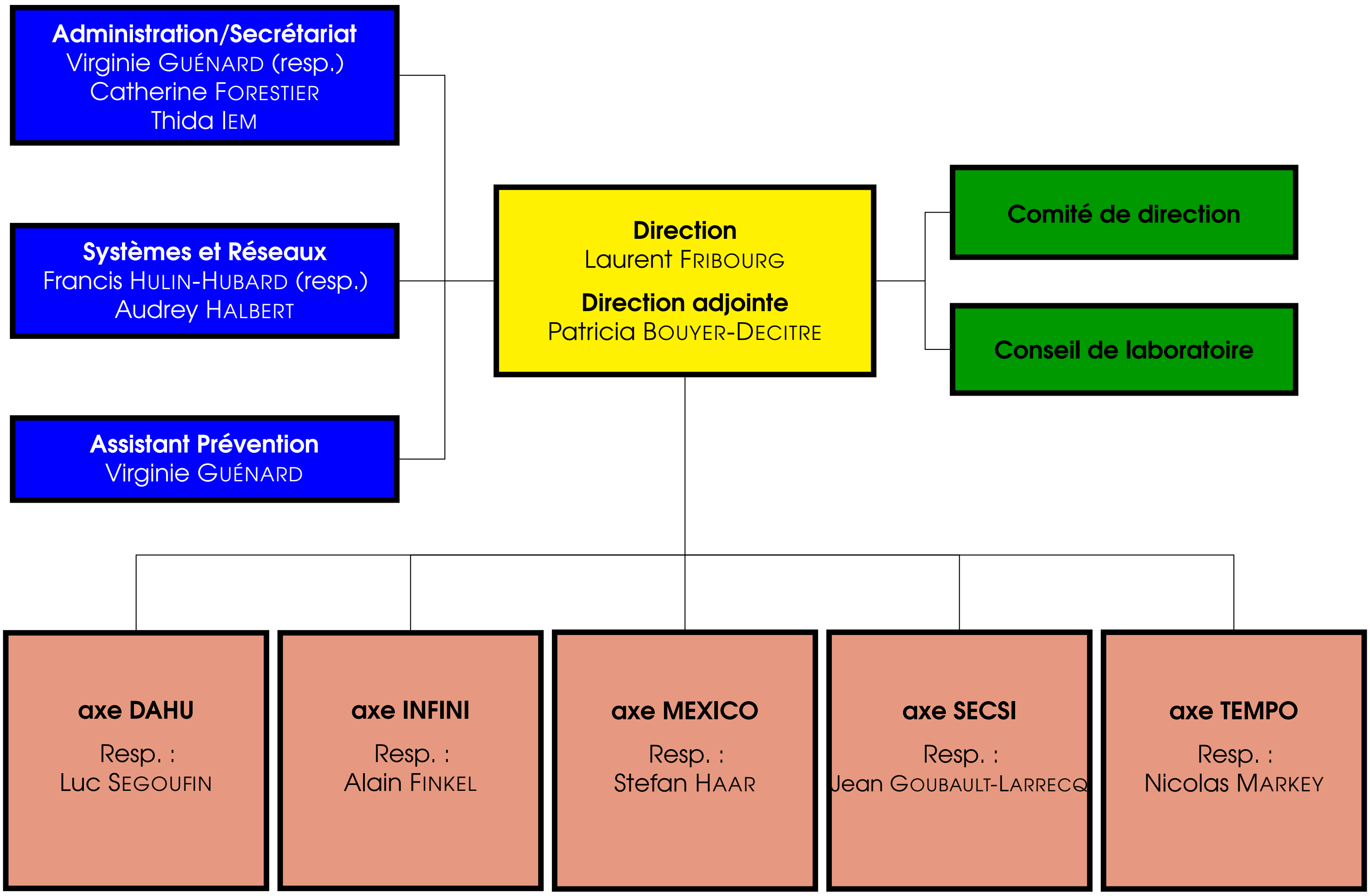
Annexe 4 :
Organigramme fonctionnel de l'unité



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Annexe 6 :

Liste des publications du Laboratoire Spécification & Vérification entre le 1er janvier 2008 et le 30 juin 2013

Livres

(LI-1) Jean Goubault-Larrecq. *Non-Hausdorff Topology and Domain Theory—Selected Topics in Point-Set Topology*, volume 22 of *New Mathematical Monographs*. Cambridge University Press, March 2013.

(LI-2) Étienne André and Romain Soulat. *The Inverse Method*. Wiley-ISTE, January 2013. 176 pages.

(LI-3) Serge Abiteboul. *Sciences des données : De la logique du premier ordre à la Toile*. Leçons inaugurales du Collège de France. Fayard, 2012.

(LI-4) Serge Abiteboul, Ioana Manolescu, Philippe Rigaux, Marie-Christine Rousset, and Pierre Senellart. *Web Data Management*. Cambridge University Press, 2011.

(LI-5) Fabrizio Luccio, Linda Pagli, and Graham Steel. *Mathematical and Algorithmic Foundations of the Internet*. CRC Press, July 2011.

Chapitres de livres

(Ch-1) Marie Duflot, Marta Kwiatkowska, Gethin Norman, David Parker, Sylvain Peyronnet, Claudine Picaronny, and Jeremy Sproston. Practical applications of probabilistic model checking to communication protocols. *In* Stefania Gnesi and Tiziana Margaria, editors, *Formal Methods for Industrial Critical Systems : A Survey of Applications*, chapter 7, pages 133–150. John Wiley & Sons, Ltd. and IEEE Computer Society Press, March 2013.

(Ch-2) Jean Goubault-Larrecq and Jean-Pierre Jouannaud. The blossom of finite semantic trees. *In* Andrei Voronkov and Christoph Weidenbach, editors, *Programming Logics – Essays in Memory of Harald Ganzinger*, volume 7797 of *Lecture Notes in Computer Science*, pages 90–122. Springer, January 2013.

(Ch-3) Stéphane Demri and Paul Gastin. Specification and verification using temporal logics. *In* Deepak D'Souza and Priti Shankar, editors, *Modern applications of automata theory*, volume 2 of *IISc Research Monographs*, chapter 15, pages 457–494. World Scientific, July 2012.

(Ch-4) Hubert Comon-Lundh, Stéphanie Delaune, and Jonathan Millen. Constraint solving techniques and enriching the model with equational theories. *In* Véronique Cortier and Steve Kremer, editors, *Formal Models and Techniques for Analyzing Security Protocols*, volume 5 of *Cryptology and Information Security Series*, pages 35–61. IOS Press, 2011.

(Ch-5) Stéphane Demri and Denis Poitrenaud. Verification of infinite-state systems. *In* Serge Haddad, Fabrice Kordon, Laurent Pautet, and Laure Petrucci, editors, *Models and Analysis in Distributed Systems*, chapter 8, pages 221–269. John Wiley & Sons, Ltd., 2011.

(Ch-6) Serge Haddad. Introduction to verification. *In* Serge Haddad, Fabrice Kordon, Laurent Pautet, and Laure Petrucci, editors, *Models and Analysis in Distributed Systems*, chapter 6, pages 137–154. John Wiley & Sons, Ltd., 2011.

(Ch-7) Graham Steel. Formal analysis of security APIs. *In* Henk C. A. van Tilborg and Sushil Jajodia, editors, *Encyclopedia of Cryptography and Security*, pages 492–494. Springer, 2nd edition, 2011.

(Ch-8) Riccardo Focardi, Flaminia L. Luccio, and Graham Steel. An introduction to security API analysis. *In* Alessandro Aldini and Roberto Gorrieri, editors, *Foundations of Security Analysis and Design – FOSAD Tutorial Lectures (FOSAD'VI)*, volume 6858 of *Lecture Notes in Computer Science*, pages 35–65. Springer, September 2011.

(Ch-9) Laurent Doyen and Jean-François Raskin. Games with imperfect information : Theory and algorithms. *In* Krzysztof R. Apt and Erich Grädel, editors, *Lectures in Game Theory for Computer Scientists*. Cambridge University Press, January 2011.

(Ch-10) Dietmar Berwanger. Infinite coordination games. *In* Giacomo Bonnano, Benedikt Löwe, and Wiebe van der Hoek, editors, *Logic and the Foundations of Game and Decision Theory (LOFT8)*, volume 6006 of *Lecture Notes in Artificial Intelligence*, pages 1–19. Springer, 2010.

(Ch-11) Stéphanie Delaune, Steve Kremer, and Mark D. Ryan. Verifying privacy-type properties of electronic voting protocols : A taster. *In* David Chaum, Markus Jakobsson, Ronald L. Rivest, Peter Y. A. Ryan, Josh Benaloh, Mirosław Kutyłowski, and Ben Adida, editors, *Towards Trustworthy Elections – New Directions in Electronic Voting*, volume 6000 of *Lecture Notes in Computer Science*, pages 289–309. Springer, May 2010.

(Ch-12) Manfred Droste and Paul Gastin. Weighted automata and weighted logics. *In* Werner Kuich, Heiko Vogler, and Manfred Droste, editors, *Handbook of Weighted Automata*, EATCS Monographs in Theoretical Computer Science, chapter 5, pages 175–211. Springer, 2009.

(Ch-13) Serge Haddad. Decidability and complexity of Petri net problems. *In* Michel Diaz, editor, *Petri Nets : Fundamental Models, Verification and Applications*, pages 87–122. Wiley-ISTE, 2009.

(Ch-14) Serge Haddad and Jean-Michel Ilié. Symmetry and temporal logic. *In* Michel Diaz, editor, *Petri Nets : Fundamental Models, Verification and Applications*, pages 435–460. Wiley-ISTE, 2009.

(Ch-15) Serge Haddad and Patrice Moreaux. Stochastic Petri nets. *In* Michel Diaz, editor, *Petri Nets : Fundamental Models, Verification and Applications*, pages 269–302. Wiley-ISTE, 2009.

(Ch-16) Serge Haddad and Patrice Moreaux. Stochastic well-formed Petri nets. *In* Michel Diaz, editor, *Petri Nets : Fundamental Models, Verification and Applications*, pages 303–320. Wiley-ISTE, 2009.

(Ch-17) Serge Haddad and Patrice Moreaux. Tensor methods and stochastic Petri nets. *In* Michel Diaz, editor, *Petri Nets : Fundamental Models, Verification and Applications*, pages 321–346. Wiley-ISTE, 2009.

(Ch-18) Serge Haddad and François Vernadat. Analysis methods for Petri nets. *In* Michel Diaz, editor, *Petri Nets : Fundamental Models, Verification and Applications*, pages 41–86. Wiley-ISTE, 2009.

(Ch-19) Serge Haddad and François Vernadat. Verification of specific properties. *In* Michel Diaz, editor, *Petri Nets : Fundamental Models, Verification and Applications*, pages 349–414. Wiley-ISTE, 2009.

(Ch-20) Franck Cassez and Nicolas Markey. Control of timed systems. *In* Claude Jard and Olivier H. Roux, editors, *Communicating Embedded Systems – Software and Design*, chapter 3, pages 83–120. Wiley-ISTE, October 2009.

(Ch-21) Alexandre David, Gerd Behrmann, Peter Bulychev, Joakin Byg, Thomas Chatain, Kim G. Larsen, Paul Pettersson, Jacob Illum Rasmussen, Jiří Srba, Wang Yi, Kenneth Y. Joergensen, Didier Lime, Morgan Magnin, Olivier H. Roux, and Louis-Marie Traonouez. Tools for model-checking timed systems. *In* Claude Jard and Olivier H. Roux, editors, *Communicating Embedded Systems – Software and Design*, chapter 6, pages 165–225. Wiley-ISTE, October 2009.

(Ch-22) Susanna Donatelli and Serge Haddad. Quantitative verification of Markov chains. *In* Claude Jard and Olivier H. Roux, editors, *Communicating Embedded Systems – Software and Design*, chapter 5, pages 139–163. Wiley-ISTE, October 2009.

(Ch-23) Reynald Affeldt and Hubert Comon-Lundh. Verification of security protocols with a bounded number of sessions based on resolution for rigid variables. *In* Véronique Cortier, Claude Kirchner, Mitsuhiro Okada, and Hideki Sakurada, editors, *Formal to Practical Security*, volume 5458 of *Lecture Notes in Computer Science*, pages 1–20. Springer, May 2009.

(Ch-24) Amal El Fallah Seghrouchni and Serge Haddad. Interopérabilité des systèmes multi-agents à l'aide des services web. *In* Amal El Fallah Seghrouchni and Jean-Pierre Briot, editors, *Technologies des systèmes multi-agents et applications industrielles*, chapter 3, pages 77–99. Hermès, April 2009.

(Ch-25) Patricia Bouyer and Antoine Petit. On extensions of timed automata. *In* Kamal Lodaya, Madhavan Mukund, and R. Ramanujam, editors, *Perspectives in Concurrency Theory*, IARCS-Universities, pages 35–63. Universities Press, January 2009.

(Ch-26) Volker Diekert and Paul Gastin. Local safety and local liveness for distributed systems. *In* Kamal Lodaya, Madhavan Mukund, and R. Ramanujam, editors, *Perspectives in Concurrency Theory*, IARCS-Universities, pages 86–106. Universities Press, January 2009.

(Ch-27) Paul Gastin, Madhavan Mukund, and K. Narayan Kumar. Reachability and boundedness in time-constrained MSC graphs. *In* Kamal Lodaya, Madhavan Mukund, and R. Ramanujam, editors, *Perspectives in Concurrency Theory*, IARCS-Universities, pages 157–183. Universities Press, January 2009.

(Ch-28) Volker Diekert and Paul Gastin. First-order definable languages. *In* Jörg Flum, Erich Grädel, and Thomas Wilke, editors, *Logic and Automata : History and Perspectives*, volume 2 of *Texts in Logic and Games*, pages 261–306. Amsterdam University Press, 2008.

(Ch-29) Franck Cassez and Nicolas Markey. Contrôle des systèmes temporisés. *In* Olivier H. Roux and Claude Jard, editors, *Approches formelles des systèmes embarqués communicants*, chapter 4, pages 105–144. Hermès, October 2008.

(Ch-30) Susanna Donatelli and Serge Haddad. Vérification quantitative de chaînes de Markov. *In* Olivier H. Roux and Claude Jard, editors, *Approches formelles des systèmes embarqués communicants*, chapter 6, pages 177–198. Hermès, October 2008.

(Ch-31) Patricia Bouyer and François Laroussinie. Model checking timed automata. *In* Stephan Merz and Nicolas Navet, editors, *Modeling and Verification of Real-Time Systems*, pages 111–140. ISTE Ltd. – John Wiley & Sons, Ltd., January 2008.

(Ch-32) Serge Haddad and Patrice Moreaux. Verification of probabilistic systems methods and tools. *In* Stephan Merz and Nicolas Navet, editors, *Modeling and Verification of Real-Time Systems*, pages 289–318. ISTE Ltd. – John Wiley & Sons, Ltd., January 2008.

Édition d'ouvrages collectifs

(Ed-1) Alain Finkel, Jérôme Leroux, and Igor Potapov, editors. *Proceedings of the 6th International Wokshop on Reachability Problems (RP'12)*, volume 7550 of *Lecture Notes in Computer Science*. Springer.

(Ed-2) Serge Haddad and Lucia Pomello, editors. *Proceedings of the 33rd International Conference on Applications and Theory of Petri Nets (ICATPN'12)*, volume 7347 of *Lecture Notes in Computer Science*. Springer.

(Ed-3) Véronique Cortier and Steve Kremer, editors. *Formal Models and Techniques for Analyzing Security Protocols*, volume 5 of *Cryptology and Information Security Series*. IOS Press, 2011.

(Ed-4) Serge Haddad, Fabrice Kordon, Laurent Pautet, and Laure Petrucci, editors. *Distributed Systems Design and Algorithms*. John Wiley & Sons, Ltd., 2011.

(Ed-5) Serge Haddad, Fabrice Kordon, Laurent Pautet, and Laure Petrucci, editors. *Models and Analysis in Distributed Systems*. John Wiley & Sons, Ltd., 2011.

(Ed-6) Serge Abiteboul, Klemens Böhm, Christoph Koch, and Kian-Lee Tan. Proceedings of the 27th International Conference on Data Engineering (ICDE'11). *In* Serge Abiteboul, Klemens Böhm, Christoph Koch, and Kian-Lee Tan, editors, *Proceedings of the 27th International Conference on Data Engineering (ICDE'11), Hannover, Germany, April 2011*. IEEE Computer Society Press.

(Ed-7) Nicolas Markey and Jef Wijsen, editors. *Proceedings of the 17th International Symposium on Temporal Representation and Reasoning (TIME'10)*. IEEE Computer Society Press.

(Ed-8) Paul Gastin and François Laroussinie, editors. *Proceedings of the 21st International Conference on Concurrency Theory (CONCUR'10)*, volume 6269 of *Lecture Notes in Computer Science*. Springer.

(Ed-9) Luc Segoufin, editor. *Proceedings of the 13th International Conference on Database Theory (ICDT'10)*.

(Ed-10) Michele Boreale and Steve Kremer, editors. *Proceedings of the 7th International Workshop on Security Issues in Concurrency (SecCo'09)*, volume 7 of *Electronic Proceedings in Theoretical Computer Science*.

(Ed-11) Steve Kremer and Prakash Panangaden, editors. *Proceedings of the 6th International Workshop on Security Issues in Concurrency (SecCo'08)*, volume 242(3) of *Electronic Notes in Theoretical Computer Science*. Elsevier Science Publishers, August 2009.

(Ed-12) Peter Habermehl and Tomáš Vojnar, editors. *Joint Proceedings of the 8th, 9th and 10th International Workshops on Verification of Infinite State Systems (INFINITY'06,'07,'08)*, volume 239 of *Electronic Notes in Theoretical Computer Science*. Elsevier Science Publishers, July 2009.

(Ed-13) Carlos Areces and Stéphane Demri, editors. *Proceedings of the 5th International Workshop on Methods for Modalities (M4M-5)*, volume 231 of *Electronic Notes in Theoretical Computer Science*. Elsevier Science Publishers, March 2009.

(Ed-14) Liqun Chen, Steve Kremer, and Mark D. Ryan, editors. *Formal Protocol Verification Applied*, volume 07421 of *Dagstuhl Seminar Proceedings*.

(Ed-15) Stéphane Demri and Christian S. Jensen, editors. *Proceedings of the 15th International Symposium on Temporal Representation and Reasoning (TIME'08)*. IEEE Computer Society Press.

Articles dans des revues internationales avec comité de lecture

(RI-1) Sandie Balaguer, Thomas Chatain, and Stefan Haar. Building occurrence nets from reveals relations. *Fundamenta Informaticae*, 123(3):245–272, 2013.

(RI-2) Stéphane Demri. On selective unboundedness of VASS. *Journal of Computer and System Sciences*, 79(5):689–713, 2013.

(RI-3) Serge Haddad, Jean Mairesse, and Hoang-Thach Nguyen. Synthesis and analysis of product-form Petri nets. *Fundamenta Informaticae*, 122(1-2):147–172, 2013.

(RI-4) S. Akshay, Benedikt Bollig, and Paul Gastin. Event-clock message passing automata : A logical characterization and an emptiness checking algorithm. *Formal Methods in System Design*, 42(3):262–300, June 2013.

(RI-5) Vincent Cheval, Véronique Cortier, and Stéphanie Delaune. Deciding equivalence-based properties using constraint solving. *Theoretical Computer Science*, 492:1–39, June 2013.

(RI-6) Paul Gastin and Nathalie Sznajder. Fair synthesis for asynchronous distributed systems. *ACM Transactions on Computational Logic*, 14(2 :9), June 2013.

(RI-7) Étienne André, Laurent Fribourg, and Jeremy Sproston. An extension of the inverse method to probabilistic timed automata. *Formal Methods in System Design*, 42(2):119–145, April 2013.

(RI-8) Luis Barguñó, Carles Creus, Guillem Godoy, Florent Jacquemard, and Camille Vacher. Decidable classes of tree automata mixing local and global constraints modulo flat theories. *Logical Methods in Computer Science*, 9(2), April 2013.

(RI-9) Rémi Bonnet, Alain Finkel, Serge Haddad, and Fernando Rosa-Velardo. Ordinal theory for expressiveness of well-structured transition systems. *Information and Computation*, 224:1–22, March 2013.

(RI-10) Mathieu Baudet, Véronique Cortier, and Stéphanie Delaune. YAPA : A generic tool for computing intruder knowledge. *ACM Transactions on Computational Logic*, 14(1 :4), February 2013.

(RI-11) Béatrice Bérard, Franck Cassez, Serge Haddad, Didier Lime, and Olivier H. Roux. The expressive power of time Petri nets. *Theoretical Computer Science*, 474:1–20, February 2013.

(RI-12) Laurent Fribourg and Ulrich Kühne. Parametric verification and test coverage for hybrid automata using the inverse method. *International Journal of Foundations of Computer Science*, 24(2):233–249, February 2013.

(RI-13) Rémi Bonnet, Alain Finkel, Jérôme Leroux, and Marc Zeitoun. Model checking vector addition systems with one zero-test. *Logical Methods in Computer Science*, 8(2 :11), 2012.

(RI-14) Dorsaf Elhog-Benzina, Serge Haddad, and Rolf Hennicker. Refinement and asynchronous composition of modal Petri nets. *In Transactions on Petri Nets and Other Models of Concurrency V*, volume 6900 of *Lecture Notes in Computer Science*, pages 96–120. Springer, 2012.

(RI-15) Diego Figueira. Alternating register automata on finite words and trees. *Logical Methods in Computer Science*, 8(1 :22), 2012.

(RI-16) Jean Goubault-Larrecq. QRB-domains and the probabilistic powerdomain. *Logical Methods in Computer Science*, 8(1 :14), 2012.

(RI-17) Dietmar Berwanger, Erich Grädel, Łukasz Kaiser, and Roman Rabinovich. Entanglement and the complexity of directed graphs. *Theoretical Computer Science*, 463:2–25, December 2012.

(RI-18) Dietmar Berwanger and Olivier Serre. Parity games on undirected graphs. *Information Processing Letters*, 112(23):928–932, December 2012.

(RI-19) Michaël Cadilhac, Alain Finkel, and Pierre McKenzie. Bounded Parikh automata. *International Journal of Foundations of Computer Science*, 23(8):1691–1710, December 2012.

(RI-20) Paul Gastin and Nathalie Sznajder. Decidability of well-connectedness for distributed synthesis. *Information Processing Letters*, 112(24):963–968, December 2012.

(RI-21) Stefan Haar. What topology tells us about diagnosability in partial order semantics. *Discrete Event Dynamic Systems : Theory and Applications*, 22(4):383–402, December 2012.

(RI-22) Matthew Anderson, Dieter van Melkebeek, Nicole Schweikardt, and Luc Segoufin. Locality from circuit lower bounds. *SIAM Journal on Computing*, 41(6):1481–1523, November 2012.

(RI-23) Krishnendu Chatterjee and Laurent Doyen. Energy parity games. *Theoretical Computer Science*, 458:49–60, November 2012.

(RI-24) Dario Faggioli, Giuseppe Lipari, and Tommaso Cucinotta. Analysis and implementation of the multiprocessor bandwidth inheritance protocol. *Real-Time Systems*, 48(6):789–825, November 2012.

(RI-25) Michaël Cadilhac, Alain Finkel, and Pierre McKenzie. Affine parikh automata. *RAIRO Informatique Théorique et Applications*, 46(4):511–545, October 2012.

(RI-26) Philippe Darondeau, Stéphane Demri, Roland Meyer, and Christophe Morvan. Petri net reachability graphs : Decidability status of FO properties. *Logical Methods in Computer Science*, 8(4 :9), October 2012.

(RI-27) Stéphane Demri, Deepak D'Souza, and Régis Gascon. Temporal logics of repeating values. *Journal of Logic and Computation*, 22(5):1059–1096, October 2012.

(RI-28) Mikołaj Bojańczyk, Luc Segoufin, and Howard Straubing. Piecewise testable tree languages. *Logical Methods in Computer Science*, 8(3 :26), September 2012.

(RI-29) Alain Finkel and Jean Goubault-Larrecq. Forward analysis for WSTS, part II : Complete WSTS. *Logical Methods in Computer Science*, 8(3 :28), September 2012.

(RI-30) Rodrigo M. Santos, Giuseppe Lipari, Enrico Bini, and Tommaso Cucinotta. On-line schedulability tests for adaptive reservations in fixed priority scheduling. *Real-Time Systems*, 48(5):601–634, September 2012.

(RI-31) Paolo Baldan, Alessandro Bruni, Andrea Corradini, Barbara König, César Rodríguez, and Stefan Schwoon. Efficient unfolding of contextual Petri nets. *Theoretical Computer Science*, 449(1):2–22, August 2012.

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Autres communications sur invitation, tutorials, ...

(In-1) Laurent Fribourg. En quoi Turing a-t-il changé ma vie ?, April 2012.

(In-2) Jean Goubault-Larrecq. A few pearls in the theory of quasi-metric spaces. Invited talk, Fifth International Conference on Topology, Algebra, and Categories in Logic (TACL'11), Marseilles, France, July 2011, July 2011.

(In-3) Leonid Libkin and Cristina Sirangelo. Open and closed world assumptions in data exchange. *In* Bernardo Cuenca Grau, Ian Horrocks, Boris Motik, and Ulrike Sattler, editors, *Proceedings of the 22nd International Workshop Description Logic (DL'09), Oxford, UK, July 2009*, volume 477 of *CEUR Workshop Proceedings*, pages 1–6. RWTH Aachen, Germany.

(In-4) Patricia Bouyer. Probabilities in timed automata. Invited talk, Workshop Automata and Verification (AV'08), Mons, Belgium, August 2008.

(In-5) Nicolas Markey. Infinite runs in weighted times games with energy constraints. Invited talk, Workshop Automata and Verification (AV'08), Mons, Belgium, August 2008.

(In-6) Philippe Schnoebelen. The complexity of lossy channel systems. Invited talk, Workshop Automata and Verification (AV'08), Mons, Belgium, August 2008.

(In-7) Nicolas Markey. Timed systems – model checking and games. Invited tutorial, 8th School on Modelling and Verifying Parallel Processes (MOVEP'08), Nouan-le-Fuzelier, France, June 2008.

(In-8) Patricia Bouyer. Model-checking timed temporal logics. *In* Tei-Wei Kuo and Samuel Cruz-Lara, editors, *Proceedings of the 4th Taiwanese-French Conference on Information Technology (TFIT'08), Taipei, Taiwan, March 2008*, pages 132–142.

(In-9) Stéphanie Delaune, Steve Kremer, and Graham Steel. Formal analysis of PKCS#11. *In* Tei-Wei Kuo and Samuel Cruz-Lara, editors, *Proceedings of the 4th Taiwanese-French Conference on Information Technology (TFIT'08), Taipei, Taiwan, March 2008*, pages 267–278.

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(CI-2) Serge Abiteboul and Victor Vianu. Collaborative data-driven workflows : Think global, act local. *In* Wenfei Fan, editor, *Proceedings of the 32nd Annual ACM SIGACT-SIGMOD-SIGART Symposium on Principles of Database Systems (PODS'13), New York, New York, USA, June 2013*, pages 91–102. ACM Press.

(CI-3) Arjun Arul and Julien Reichert. The complexity of robot games on the integer line. *In* Luca Bortolussi and Herbert Wiklicky, editors, *Proceedings of the 11th International Workshop on Quantitative Aspects of Programming Languages (QAPI'13), Rome, Italy, June 2013*, volume 117 of *Electronic Proceedings in Theoretical Computer Science*, pages 132–148.

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(CI-5) Mikołaj Bojańczyk, Luc Segoufin, and Szymon Toruńczyk. Verification of database-driven systems via amalgamation. *In* Wenfei Fan, editor, *Proceedings of the 32nd Annual ACM SIGACT-SIGMOD-SIGART Symposium on Principles of Database Systems (PODS'13), New York, New York, USA, June 2013*, pages 63–74. ACM Press.

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(TH-2) Rémi Bonnet. Theory of well-structured transition systems and extended vector-addition systems. Thèse de doctorat, Laboratoire Spécification et Vérification, ENS Cachan, France, January 2013.

(TH-3) Sandie Balaguer. La concurrence dans les systèmes distribués temps-réel. Thèse de doctorat, Laboratoire Spécification et Vérification, ENS Cachan, France, December 2012.

(TH-4) Hedi Benzina. Enforcing virtualized systems security. Thèse de doctorat, Laboratoire Spécification et Vérification, ENS Cachan, France, December 2012.

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(TH-6) Romain Brenguier. Équilibres de Nash dans les jeux concurrents – Application aux jeux temporisés. Thèse de doctorat, Laboratoire Spécification et Vérification, ENS Cachan, France, November 2012.

(TH-7) Étienne Lozes. Separation logic : Expressiveness and copyless message-passing. Mémoire d'habilitation, École Normale Supérieure de Cachan, France, July 2012.

(TH-8) Hilal Djafri. Approches numériques et statistiques pour le model checking des processus stochastiques. Thèse de doctorat, Laboratoire Spécification et Vérification, ENS Cachan, France, June 2012.

(TH-9) Laurent Doyen. Games and automata : From boolean to quantitative verification. Mémoire d'habilitation, École Normale Supérieure de Cachan, France, March 2012.

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(TH-15) Alban Galland. Distributed data management with access control. Thèse de doctorat, Laboratoire Spécification et Vérification, ENS Cachan, France, September 2011.

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(TH-18) Steve Kremer. Modelling and analyzing security protocols in cryptographic process calculi. Mémoire d'habilitation, École Normale Supérieure de Cachan, France, March 2011.

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(Ra-19) Dietmar Berwanger, Łukasz Kaiser, and Simon Leßenich. Imperfect recall and counter games. Research Report LSV-11-20, Laboratoire Spécification et Vérification, ENS Cachan, France, October 2011.

(Ra-20) Jan Degrieck. *Réduction de graphes pour l'analyse de protocoles de routage sécurisés*. Rapport de Master, Master Parisien de Recherche en Informatique, Paris, France, September 2011.

(Ra-21) Amit Kumar Dhar. *Counter Systems with Presburger-definable Reachability Sets : Decidability and Complexity*. Rapport de Master, Master Parisien de Recherche en Informatique, Paris, France, September 2011.

(Ra-22) Daniel Pasailă. *Verifying equivalence properties of security protocols*. Rapport de Master, Master Parisien de Recherche en Informatique, Paris, France, September 2011.

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(Ra-27) Rémi Bonnet, Alain Finkel, Serge Haddad, and Fernando Rosa-Velardo. Comparing petri data nets and timed petri nets. Research Report LSV-10-23, Laboratoire Spécification et Vérification, ENS Cachan, France, December 2010. 16 pages.

(Ra-28) Romain Soulat. On properties of the inverse method : Commutation of instanciation and full covering of the behavioral cartography. Research Report LSV-10-22, Laboratoire Spécification et Vérification, ENS Cachan, France, December 2010. 14 pages.

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(Ra-31) Adrien Boiret. *Grammaires Context-Free pour les arbres sans rang*. Rapport de Master, Master Parisien de Recherche en Informatique, Paris, France, September 2010.

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(Ra-33) Jérémie Dimino. *Sur les arbres de rang non borné avec données*. Rapport de Master, Master Parisien de Recherche en Informatique, Paris, France, September 2010.

(Ra-34) Benjamin Monmege. *Propriétés quantitatives des mots et des arbres – Applications aux langages XML*. Rapport de Master, Master Parisien de Recherche en Informatique, Paris, France, September 2010.

(Ra-35) César Rodríguez. *Implementation of a complete prefix unfolder for contextual nets*. Rapport de Master, Master Parisien de Recherche en Informatique, Paris, France, September 2010.

(Ra-36) Ocan Sankur. *Model-checking robuste des automates temporisés via les machines à canaux*. Rapport de Master, Master Parisien de Recherche en Informatique, Paris, France, September 2010.

(Ra-37) Guillaume Scerri. *Modélisation des clés de l'intrus*. Rapport de Master, Master Parisien de Recherche en Informatique, Paris, France, September 2010.

(Ra-38) Romain Soulat. *Améliorations algorithmiques d'un moteur de model-checking et études de cas*. Rapport de Master, Master 2 Recherche Informatique Paris Sud 11, September 2010.

(Ra-39) Rémi Bonnet. *Well-structured Petri Nets extensions with data*. Rapport de Master, Master Computer Science, EPFL, Lausanne, Switzerland, March 2010.

(Ra-40) Jérémie Dimino. *Les systèmes à canaux non-fiables vus comme des transducteurs*. Rapport de stage de M1, Master Parisien de Recherche en Informatique, Paris, France, October 2009.

(Ra-41) Romain Brenguier. *Calcul des équilibres de Nash dans les jeux temporisés*. Rapport de Master, Master Parisien de Recherche en Informatique, Paris, France, September 2009.

(Ra-42) Vincent Cheval. *Algorithme de décision de l'équivalence symbolique de systèmes de contraintes*. Rapport de Master, Master Parisien de Recherche en Informatique, Paris, France, September 2009.

(Ra-43) Étienne André. Everything you always wanted to know about IMITATOR (but were afraid to ask). Research Report LSV-09-20, Laboratoire Spécification et Vérification, ENS Cachan, France, July 2009. 11 pages.

(Ra-44) Béatrice Bérard, Serge Haddad, and Mathieu Sassolas. Verification on interrupt timed automata. Research Report LSV-09-16, Laboratoire Spécification et Vérification, ENS Cachan, France, July 2009. 16 pages.

(Ra-45) Pierre-Cyrille Héam and Cyril Nicaud. Seed : an easy-to-use random generator of recursive data structures for testing. Research Report LSV-09-15, Laboratoire Spécification et Vérification, ENS Cachan, France, July 2009. 16 pages.

(Ra-46) Étienne André, Emmanuelle Encrenaz, and Laurent Fribourg. Synthesizing parametric constraints on various case studies using IMITATOR. Research Report LSV-09-13, Laboratoire Spécification et Vérification, ENS Cachan, France, June 2009. 18 pages.

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(Ra-51) Alain Finkel and Jérôme Leroux. Presburger functions are piecewise linear. Research Report LSV-08-08, Laboratoire Spécification et Vérification, ENS Cachan, France, March 2008. 9 pages.

(Ra-52) Jules Villard, Étienne Lozes, and Ralf Treinen. A spatial equational logic for the applied pi-calculus. Research Report LSV-08-10, Laboratoire Spécification et Vérification, ENS Cachan, France, March 2008. 44 pages.

(Ra-53) Elie Bursztein. Network administrator and intruder strategies. Research Report LSV-08-02, Laboratoire Spécification et Vérification, ENS Cachan, France, February 2008. 23 pages.

Rapports de contrats

(Rc-1) Sandie Balaguer, Thomas Chatain, and Stefan Haar. Concurrent semantics for timed distributed systems. Deliverable ImpRo D 4.1 (ANR-2010-BLAN-0317), March 2012.

(Rc-2) Radu Iosif, Peter Habermehl, Sebastien Labbe, Étienne Lozes, and Boris Yakobowski. Concurrent programs with simple data structures / sequential programs with composite data structures. Deliverable VERIDYC D 2 (ANR-09-SEGI-016), March 2012.

(Rc-3) S. Akshay, Béatrice Bérard, Patricia Bouyer, Stefan Haar, Serge Haddad, Claude Jard, Didier Lime, Nicolas Markey, Pierre-Alain Reynier, Ocan Sankur, and Yann Thierry-Mieg. Overview of robustness in timed systems. Deliverable ImpRo D 2.1 (ANR-2010-BLAN-0317), January 2012.

(Rc-4) Étienne André, Abdelrezzak Bara, Pirouz Bazargan-Sabet, Rémy Chevallier, Dominique Le Dû, Emmanuelle Encrenaz, Laurent Fribourg, and Patricia Renault. Compte-rendu de fin du projet ANR VALMEM, January 2011. 14 pages.

(Rc-5) Stéphanie Delaune. Algorithms for observational equivalence. Deliverable AVOTE 2.2, (ANR-07-SESU-002), January 2011. 118 pages.

(Rc-6) Steve Kremer. Results on case studies from literature. Deliverable AVOTE 4.2, (ANR-07-SESU-002), January 2011. 96 pages.

(Rc-7) Étienne André, Abdelrezzak Bara, Pirouz Bazargan-Sabet, Rémy Chevallier, Dominique Le Dû, Emmanuelle Encrenaz, Laurent Fribourg, and Patricia Renault. Experiments of prototype tools on case studies, comparison of obtained results and conclusion. Deliverables VALMEM 4.2 and 4.3, (ANR-06-ARFU-005), December 2010. 31 pages.

(Rc-8) Stéphanie Delaune and Steve Kremer. Formalising security properties in electronic voting protocols. Deliverable AVOTE 1.2, (ANR-07-SESU-002), April 2010. 17 pages.

(Rc-9) Véronique Cortier, Steve Kremer, and Pascal Lafourcade. Computational soundness of static equivalence. Deliverable AVOTE 3.1, (ANR-07-SESU-002), March 2010. 106 pages.

(Rc-10) Nicolas Markey, Shuhao Li, Jean-François Raskin, and Mariëlle Stoelinga. Synthesizing controllers with bounded resources. Deliverable QUASIMODO 3.4 (ICT-FP7-STREP-214755), January 2010.

(Rc-11) LIAFA, CRIL, EDF, LSV, and Verimag. Projet RNTL Averiles – fourniture f2.2 : Algorithmes de vérification – rapport final, November 2009. 25 pages.

(Rc-12) Ştefan Ciobâcă and Véronique Cortier. Algorithmes pour l'équivalence statique. Deliverable AVOTE 2.1 (ANR-07-SESU-002), September 2009. 17 pages.

(Rc-13) François Laroussinie, Frits Vaandrager, and Martin Neuhäußer. Extended timed automata for scheduling. Deliverable QUASIMODO 3.5 (ICT-FP7-STREP-214755), July 2009.

(Rc-14) Nicolas Markey, Jasper Berendsen, Alexandre David, Tingting Han, Holger Hermanns, Kim G. Larsen, and Martin Neuhäußer. Symbolic data structures and analysis of models with multiple quantitative aspects. Deliverable QUASIMODO 2.2 (ICT-FP7-STREP-214755), July 2009.

(Rc-15) Patricia Bouyer, François Laroussinie, Didier Lime, and Nicolas Markey. Synthesis of timed controllers. Deliverable DOTS 1.2a (ANR-06-SETI-003), March 2009.

(Rc-16) Thomas Chatain, Paul Gastin, Anca Muscholl, Nathalie Sznajder, Igor Walukiewicz, and Marc Zeitoun. Distributed control for restricted specifications. Deliverable DOTS 2.2 (ANR-06-SETI-003), March 2009.

(Rc-17) Patricia Bouyer, Joost-Pieter Katoen, Rom Langerak, François Laroussinie, Nicolas Markey, and Jean-François Raskin. Transfer of correctness from models to implementation. Deliverable QUASIMODO 3.1 (ICT-FP7-STREP-214755), January 2009.

(Rc-18) Stéphanie Delaune and Steve Kremer. Spécificités des protocoles de vote électronique. Deliverable AVOTE 1.1 (ANR-07-SESU-002), January 2009. 8 pages.

(Rc-19) Benedikt Bollig, Patricia Bouyer, Franck Cassez, Thomas Chatain, Paul Gastin, Serge Haddad, and Claude Jard. Model for distributed timed systems. Deliverable DOTS 3.1 (ANR-06-SETI-003), September 2008.

(Rc-20) Franck Cassez, François Laroussinie, Didier Lime, and Nicolas Markey. Quantitative objectives in timed games. Deliverable DOTS 1.1 (ANR-06-SETI-003), September 2008.

(Rc-21) François Laroussinie et al. Projet dots (anr-06-seti-003) : Rapport à 18 mois, September 2008. 5 pages.

(Rc-22) François Laroussinie et al. Projet dots (anr-06-seti-003) : Rapport à 12 mois, March 2008. 6 pages.

Réalisations informatiques

(Lo-1) Romain Brenguier. PRALINE, 2013.

(Lo-2) Ocan Sankur. Shrinktech, 2013.

(Lo-3) Julien Olivain, Jean Goubault-Larrecq, Hedi Benzina, Baptiste Gourdin, and Romdhane Ben Younès. ORCHIDS, 2011.

(Lo-4) Étienne André, Romain Soulat, and Ulrich Kühne. Imitator II, March 2011.

(Lo-5) César Rodríguez and Stefan Schwoon. Cunf, February 2011.

(Lo-6) Jules Villard and Étienne Lozes. Heap-hop, February 2011.

(Lo-7) Ştefan Ciobâcă. KiSs, 2010.

(Lo-8) Matteo Bortolozzo, Matteo Centenaro, Riccardo Focardi, and Graham Steel. Tookan, December 2010.

(Lo-9) Étienne André. Imitator, August 2009.

(Lo-10) Étienne André. Imprator, April 2009.

(Lo-11) Jean Goubault-Larrecq. HimML : **H**imML **is** a **m**ap-oriented **ML**, December 2008.

(Lo-12) Elie Bursztein. Netanalyzer v0.7.5, January 2008. Written in C and Perl (about 25000 lines).

(Lo-13) Jean Goubault-Larrecq. The h1 tool suite, January 2008.

agence d'évaluation de la recherche et de l'enseignement supérieur

Annexe 7 :
Liste des thèses

Liste des thèses de doctorat

Thèses soutenues entre le 1er janvier 2008 et le 30 juin 2013

- Ocan SANKUR. *Robustness in Timed Automata : Analysis, Synthesis, Implementation*. Thèse de doctorat soutenue le 24 mai 2013. (TH-1).
- Rémi BONNET. *Theory of well-structured transition systems and extended vector-addition systems*. Thèse de doctorat soutenue le 22 janvier 2013. (TH-2).
- Hedi BENZINA. *Enforcing virtualized systems security*. Thèse de doctorat soutenue le 17 décembre 2012. (TH-4).
- Sandie BALAGUER. *La concurrence dans les systèmes distribués temps-réel*. Thèse de doctorat soutenue le 13 décembre 2012. (TH-3).
- Vincent CHEVAL. *Automatic verification of cryptographic protocols : privacy-type properties*. Thèse de doctorat soutenue le 03 décembre 2012. (TH-5).
- Romain BRENGUIER. *Équilibres de Nash dans les jeux concurrents – Application aux jeux temporisés*. Thèse de doctorat soutenue le 29 novembre 2012. (TH-6).
- Hilal DJAFRI. *Approches numériques et statistiques pour le model checking des processus stochastiques*. Thèse de doctorat soutenue le 19 juin 2012. (TH-8).
- Mathilde ARNAUD. *Formal verification of secured routing protocols*. Thèse de doctorat soutenue le 13 décembre 2011. (TH-10).
- Ştefan CIOBÂCĂ. *Automated verification of security protocols with appplications to electronic voting*. Thèse de doctorat soutenue le 09 décembre 2011. (TH-11).
- Pierre CHAMBARD. *Du problème de sous-mot de Post et de la complexité des canaux non fiables*. Thèse de doctorat soutenue le 29 septembre 2011. (TH-13).
- Alban GALLAND. *Distributed data management with access control*. Thèse de doctorat soutenue le 28 septembre 2011. (TH-15).
- Arnaud DA COSTA LOPES. *Propriétés de jeux multi-agents*. Thèse de doctorat soutenue le 20 septembre 2011. (TH-14).
- Jules VILLARD. *Heaps and hops*. Thèse de doctorat soutenue le 18 février 2011. (TH-21).
- Pierre BOURHIS. *On the dynamics of active documents for distributed data management*. Thèse de doctorat soutenue le 11 février 2011. (TH-20).

- Thomas Place. *Decidable characterizations for tree logics*. Thèse de doctorat soutenue le 10 décembre 2010. (TH-24).
- Étienne André. *An inverse method for the synthesis of timing parameters in concurrent systems*. Thèse de doctorat soutenue le 08 décembre 2010. (TH-22).
- Camille Vacher. *Automates à contraintes globales pour la vérification de propriétés de sécurité*. Thèse de doctorat soutenue le 07 décembre 2010. (TH-25).
- Diego Figueira. *On decidable automata on data words and data trees in relation to satisfiability of LTL and XPath*. Thèse de doctorat soutenue le 06 décembre 2010. (TH-23).
- S. Akshay. *Spécification et vérification pour des systèmes distribués et temporisés*. Thèse de doctorat soutenue le 02 juillet 2010. (TH-26).
- Jean-Loup Carré. *Analyse statique de programmes multi-thread pour l'embarqué*. Thèse de doctorat soutenue le 02 juillet 2010. (TH-27).
- Antoine Mercier. *Contributions à l'analyse automatique des protocoles cryptographiques en présence de propriétés algébriques : protocoles de groupe, équivalence statique*. Thèse de doctorat soutenue le 04 décembre 2009. (TH-29).
- Sergiu Bursuc. *Contraintes de déductibilité dans une algèbre quotient : réduction de modèles et applications à la sécurité*. Thèse de doctorat soutenue le 01 décembre 2009. (TH-28).
- Nathalie Sznajder. *Synthèse de systèmes distribués ouverts*. Thèse de doctorat soutenue le 12 novembre 2009. (TH-31).
- Florent Bouchy. *Logiques et modèles pour la vérification de systèmes infinis*. Thèse de doctorat soutenue le 10 novembre 2009. (TH-30).
- Najla Chamseddine. *Analyse quantitative parametrée d'automates temporisés probabilistes*. Thèse de doctorat soutenue le 27 octobre 2009. (TH-32).
- Ghassan Oreiby. *Logiques temporelles pour le contrôle temporisé*. Thèse de doctorat soutenue le 08 décembre 2008. (TH-34).
- Elie Bursztein. *Anticipation games. Théorie des jeux appliqués à la sécurité réseau*. Thèse de doctorat soutenue le 26 novembre 2008. (TH-36).
- Arnaud Sangnier. *Vérification de systèmes avec compteurs et pointeurs*. Thèse de doctorat soutenue le 21 novembre 2008. (TH-37).

Liste des thèses en cours au 1er juillet 2013

- Émilien Antoine. *Partage d'informations dans un réseau social*. Thèse de doctorat commencée en septembre 2010.
- Benoît Barbot. *Accélérations pour le model checking statistique*. Thèse de doctorat commencée en septembre 2011.
- Rémi Brochenin. *Separation Logic : Expressiveness, Complexity, Temporal Extension*. Thèse de doctorat commencée en septembre 2007.
- Rémy Chrétien. *Vérification de propriétés d'anonymat pour les protocoles sécurisés*. Thèse de doctorat commencée en octobre 2012.
- Aiswarya Cyriac. *Logique temporelle pour les systèmes récursifs et concurrents*. Thèse de doctorat commencée en octobre 2010.
- Nadime Francis. *Graph data processing*. Thèse de doctorat commencée en septembre 2011.
- Prateek Karandikar. *Post embedding problems and algorithmic verification for infinite state systems*. Thèse de doctorat commencée en septembre 2012.
- Wojtech Kazana. *Query evaluation with constant delay*. Thèse de doctorat commencée en mars 2010.

- Robert KÜNNEMANN. *Foundations for analysing security APIs*. Thèse de doctorat commencée en septembre 2010.
- Benjamin MONMEGE. *Vérification de propriétés quantitatives – Applications aux requêtes pour documents XML*. Thèse de doctorat commencée en septembre 2010.
- Hernan PONCE DE LEON. *Test de systèmes concurrents à l'aide de structures d'évènements*. Thèse de doctorat commencée en septembre 2011.
- Julien REICHERT. *Games with counters : decidability and algorithms*. Thèse de doctorat commencée en septembre 2011.
- César RODRÍGUEZ. *Contextual Petri nets and their applications*. Thèse de doctorat commencée en septembre 2010.
- Guillaume SCERRI. *Preuves abstraites de protocoles cryptographiques concrets*. Thèse de doctorat commencée en septembre 2011.
- Mahsa SHIRMOHAMMADI. *Quantitative verification for reactive systems*. Thèse de doctorat commencée en octobre 2010.
- Romain SOULAT. *Synthèse de contrôle pour les systèmes hybrides*. Thèse de doctorat commencée en octobre 2010.
- Marie VAN DEN BOGAARD. *Information-flow patterns and cores*. Thèse de doctorat commencée en septembre 2012.

Liste des thèses d'habilitation

- Étienne LOZES. *Separation logic : Expressiveness and copyless message-passing*. Thèse d'habilitation soutenue le 03/07/2012. (TH-7).
- Laurent DOYEN. *Games and automata : From boolean to quantitative verification*. Thèse d'habilitation soutenue le 13/03/2012. (TH-9).
- Florent JACQUEMARD. *Extended tree automata for the verification of infinite state systems*. Thèse d'habilitation soutenue le 10/11/2011. (TH-12).
- Nicolas MARKEY. *Verification of embedded systems – algorithms and complexity*. Thèse d'habilitation soutenue le 08/04/2011. (TH-16).
- Stéphanie DELAUNE. *Verification of security protocols : from confidentiality to privacy*. Thèse d'habilitation soutenue le 18/03/2011. (TH-17).
- Steve KREMER. *Modelling and analyzing security protocols in cryptographic process calculi*. Thèse d'habilitation soutenue le 17/03/2011. (TH-18).
- Graham STEEL. *Formal analysis of security APIs*. Thèse d'habilitation soutenue le 17/03/2011. (TH-19).
- Patricia BOUYER. *From qualitative to quantitative analysis of timed systems*. Thèse d'habilitation soutenue le 12/01/2009. (TH-33).